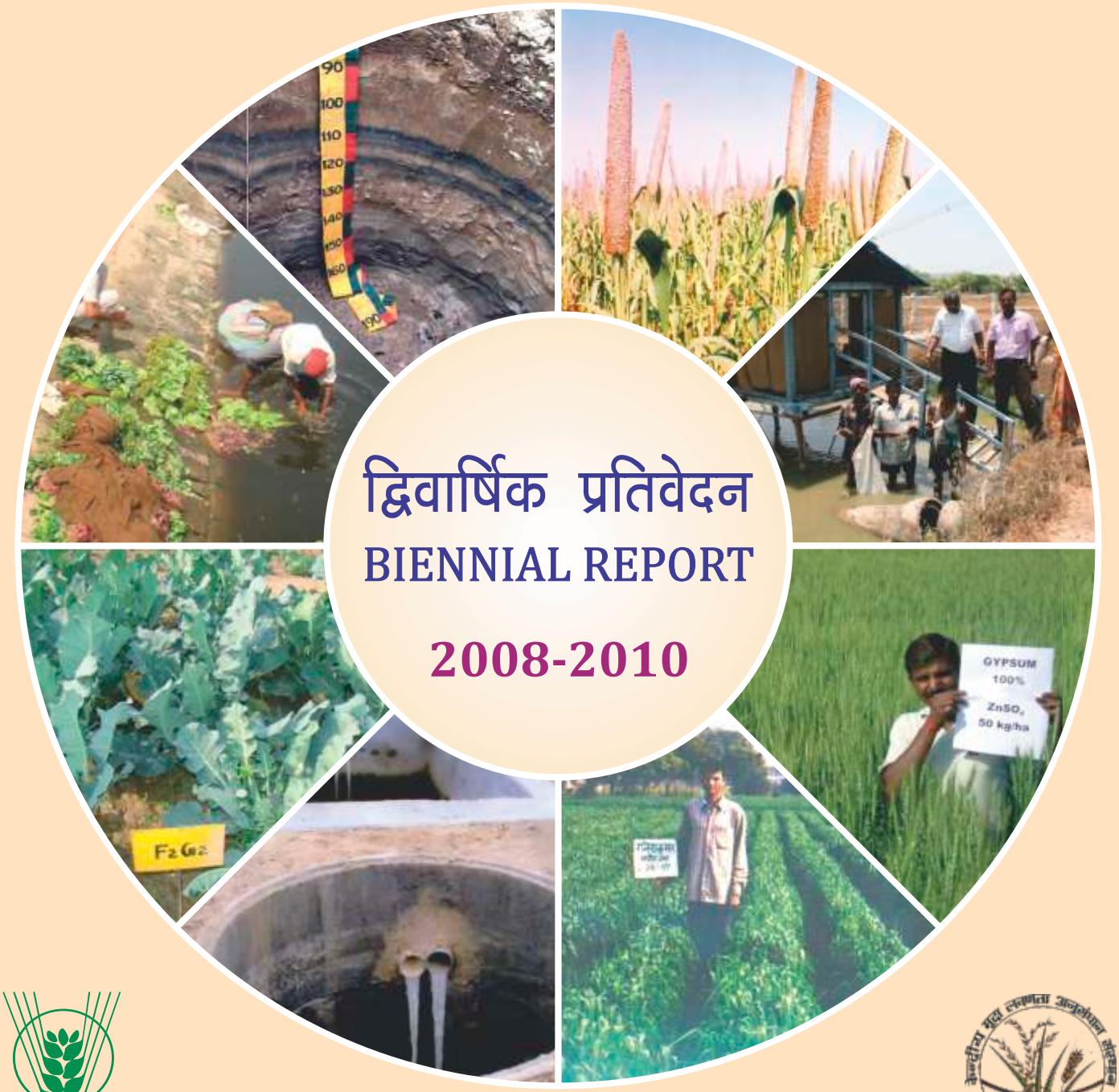
All India Coordinated Research Project
on
MANAGEMENT OF SALT AFFECTED SOILS AND USE OF SALINE WATER IN AGRICULTURE



द्विवार्षिक प्रतिवेदन
BIENNIAL REPORT
2008-2010

भाकृअनुप
ICAR

Coordinating Unit
CENTRAL SOIL SALINITY RESEARCH INSTITUTE
KARNAL – 132 001 (INDIA)


60
70
80
90
100
110
120


GYPSUM
100%
ZnSO4
50 kg/ha


F2G2

All India Coordinated Research Project

on

Management of Salt Affected Soils and Use of Saline Water in Agriculture

Biennial Report
(2008-10)

Cooperating Centers

1. R.B.S. College of Agriculture, Bichpuri, Agra – 283 105 (Uttar Pradesh)
2. Regional Research Station, Acharya N.G. Ranga Agricultural University, Bapatla – 522 101 (Andhra Pradesh)
3. S.K. Rajasthan Agricultural University, Bikaner – 334 002 (Rajasthan)
4. Agricultural Research Station, University of Agricultural Sciences, Gangawati, Koppal – 583 227 (Karnataka)
5. Department of Soils, C.C.S. Haryana Agricultural University, Hisar - 125 004 (Haryana)
6. Agricultural College, M.V.R.S. Krishi Vishwa Vidyalaya, Indore - 452 001 (Madhya Pradesh)
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भाकृअनुप
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Coordinating Unit
Central Soil Salinity Research Institute
Karnal - 132 001 (India)

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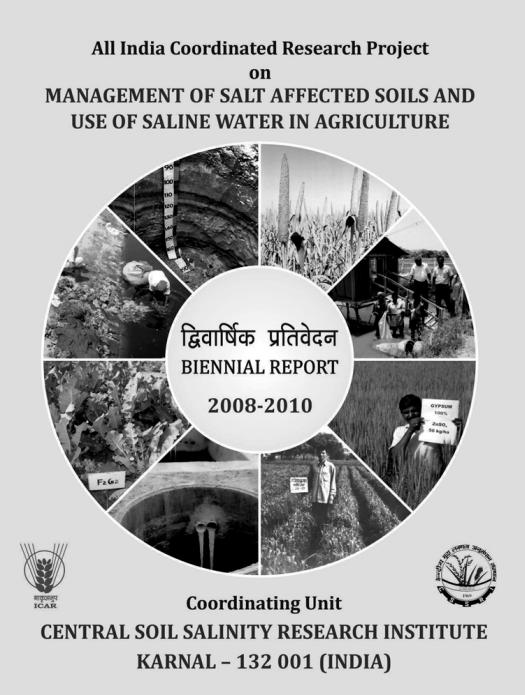

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FOREWORD

Agriculture sector is being confronted with numerous challenges linked to national food and nutritional security, energy crisis, impact of climate change and degradation of natural resources. Degradation of water quality is of particular concern as water resources, both surface and point sources such as ground water, are being increasingly polluted through non-point sources such as agriculture and unscientific disposal of industrial pollutants and municipal effluents. The sector is also struggling with decelerating profitability impacting farmer's livelihood and impinging upon its performance. Declining water table and its impact on water quality and energy needs has assumed serious dimension raising concerns on the hydrological sustainability of intensive irrigated cropping systems forming the backbone of India's food grain production. Contrarily, the demand for agricultural commodities is steeply rising not only because of the increasing population but also because of food preferences of the next-generation consumers. With fears of diversification of prime lands and pristine water to other sectors looming large, the increase in production and productivity needs to be ensured through the use of poor quality land and water resources. Under this scenario, 6.73 M ha of degraded salt affected soils could be turned into an opportunity, irrigation with naturally occurring saline/alkali waters and inadequately treated domestic/industrial effluents could help to tide the fresh water crunch in the agricultural sector. It is matter of great satisfaction that the Central Soil Salinity Research Institute, Karnal and All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture with its eight Centres in seven states came out with innovative technologies for the reclamation of salt affected soils and use of saline water in the country. As a result, about 1.8 million ha salt affected lands could be reclaimed adding about 12-15 million tonnes of food grains annually to the food grain basket of the nation. Recent initiatives of these organizations in the fields of multiple uses of water, resource conservation technologies, ground water recharge etc would prove to be highly useful to increase production, enhance profitability, improve soil and water quality and combat the challenges posed by climate change.

The eight centres of AICRP located in various agro-ecological settings besides independently working on location specific problems also act as outreach network centres of CSSRI. It is satisfying that soil and ground water characterisation studies being undertaken in different states are being synthesized to produce soil and ground water quality maps and to finalize new criteria and guidelines for their use. Experiments on conjunctive use of alkali and canal waters, use of poor quality waters using FYM and gypsum as amendments, testing and assessment of improved irrigation methods for different crops and cropping systems, management of heavy textured soils under irrigated and rain fed environment, use of agro-chemicals to minimize alkalinity hazards, status of fluoride and nitrate in ground water and impact of saline water on groundwater quality, soil properties and crop performance have given new insights into the problems and led to improved technologies. Several of these technologies notably reclamation of black alkali soils, skimming wells and alternative technologies to develop water resources in coastal sandy soils and cost effective agronomical interventions to mange saline/alkali waters are being demonstrated through ORPs and field demonstrations. The technology transfer programmes have yielded rich dividends as the technologies could be tested under farmer's endowment. I believe that the site-specific technologies developed by the Coordinating Unit and Cooperating Centres have the potential of application not only within the states but also beyond the boundaries of the state.

The current report contains the research results of the biennium 2008-10 carried out at coordinating unit and 8 research centres covering arid, semiarid, irrigated, rain fed and coastal ecologies on alluvial, Vertisols and coastal waterlogged saline/alkali soils. The current biennial workshop is being organized at a time when the process of XII plan formulation is just to begin. An interface meeting of the AICRP with the honourable DG, ICAR Dr. S. Ayyappan Ji is being held very shortly. I and the AICRP staff are indebted to Dr. Ayyappan Ji for this initiative as it would provide the AICRP staff an opportunity to discuss their achievements and problems. The QRT chaired by Dr. S. S. Khanna, former Sr. Advisor to planning commission is reviewing the progress of last five years for CSSRI as well as the AICRP centres. The team has already visited few centres in this connection. The framework suggested by the Honourable DG, ICAR and views and suggestions expressed by the

QRT team would be reflected in the new programme to be proposed by the centres and later in the SFC memo of the XII plan. I am sure that with the collective wisdom of invited experts, CSSRI scientific staff and scientists of AICRP centres, it would be possible to develop a innovative programme that would be able to address the current challenges of soil quality, ground water depletion and pollution particularly by fluoride and nitrate, dry land salinity, wastewater use, water logging and subsurface drainage, use of remote sensing and GIS for preparation of soil and water quality maps, environmental degradation and climatic change.

At the end, I record my appreciation and congratulate Dr. S.K. Gupta, Project Coordinator, and the entire staff of the PC unit for their concerted efforts in coordinating the activities during the last two years and in bringing out the biennial report. I have a special word of appreciation for Dr. R. L. Meena Scientist (SS) and Dr. Anil Chinchmalatpure, Principal Scientist who have painstakingly compiled and edited the report and brought out its printed version in the shortest possible time. I assure my and CSSRI staff full support to the project that may be required to achieve the targets set forth in the biennial workshop.

(D. K. Sharma)
Director

PREFACE

At the beginning of the second decade of the 21st century, India's population stood at 1.21 billion. In spite of some respite in the rate of increase in the population during the last decade, it has in no way diminished our food and nutritional security concerns. On the other hand, diminishing per capita land and water resources, tremendous pressure to release best quality land and water to other sectors of economy and increasing soil and water pollution are causing severe strains on production and productivity in agriculture. As such, the state of the land and water resources and its impact on agriculture is worrying all the stakeholders as problems are complex and manifold. Under this scenario, poor quality land and water resources would come to the rescue of agriculture sector provided we have simple and effective technologies that would blunt the adverse impacts of poor quality land and water resources on production, productivity and product quality. In this context, several pioneering accomplishments have been made by Central Soil Salinity Research Institute and AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture that helped to revert back the productivity of barren salt affected lands and facilitated the use of saline/alkali waters for irrigation.

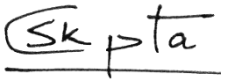
The AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture established in 1972 with 5 centers is currently being operated at 8 centers covering 7 states under the leadership of Central Soil Salinity Research Institute, Karnal, which nourishes the project with all kinds of support. The multi-disciplinary teams of scientists at each center are engaged in developing technologies to solve local problems as well as to develop regional and national guidelines on management of salt affected soils and use of saline water in agriculture. Besides, AICRP centers provide support to CSSRI in adopting and transferring its technologies in the areas of their jurisdiction with local specific modifications. The current report highlights the salient achievements made under the project during the biennium 2008-10. Soils and ground water quality surveys, nitrate and fluoride contamination of ground water, resource generation through skimming structures, subsurface drainage, salt tolerance of crops including medicinal and aromatic plants, ground water quality improvement through ground water recharge, reclamation of abandoned aqua ponds, pressurized irrigation techniques for water conservation and application of saline/alkali water are some of the technologies and processes that have been included besides providing information on publications brought out by the scientists, budget utilized, staff strength etc.

I take this opportunity to express my sincere thanks and gratitude to Dr. S. Ayyappan, Secretary, DARE & Director General (ICAR) for providing financial support to the project and for taking keen interest in its activities. His initiative, the first of its kind, to monitor the activities of the project by interacting with the OICs would help to further strengthen the functioning of the project. I also express my deep sense of gratitude to Dr. A.K. Singh, Deputy Director General (NRM) for guiding the technical program and providing unstinted support to the project.

Heart felt thanks are due to Dr. P.S. Minhas, Assistant Director General (Soil and Water) who has extended full support to the project whenever asked for and more so after joining at the Council. His continuous guidance to the project is a source of inspiration to the project staff. Thanks are also due to Dr. J. C. Dagar, ADG (Agronomy and Agro-forestry) for his excellent support to the project and Dr. P.P. Biswas for cooperation in all spheres. It is my bounden duty to thank Dr. D.K. Sharma, Director, CSSRI, Karnal for providing support and facilities to the project as well as ensuring greater interaction between the Institute and AICRP Centers.

The excellent cooperation and team spirit exhibited by my colleagues at different AICRP centers is exemplary and praise worthy. The willing cooperation extended by Dr. Bhu Dayal, Dr. (Mrs.) G.V. Lakshmi, Dr. Y. Sharma/Dr. A.K. Singh/Dr. Kumawat, Dr. M. Hebbara/ Dr. S.L. Budihal, Dr. U.R. Khandkar, Dr. Samir Pal/Dr. R. Singh, Dr. M. Sheik Dawood and Dr. S.K. Sharma in undertaking research programs as well as in compiling reports of the centers in time deserves appreciation. The staff at the coordinating unit has extended willing support of all kinds that helped in the smooth running of the project. For this excellent support and cooperation, I wish to extend heartfelt thanks to Dr. R.L. Meena, Dr. Anil Chinchmalatpure and Sh. S. P. Gupta.

Special thanks to them are also due for compiling and editing the report. Thanks are due to Smt. Rita who has gone beyond her normal duty in providing secretarial support in preparing several important documents and reports in a time bound manner. Efforts of Sh. Brij Mohan and Sh. Sukhbir Singh at various stages of report preparation are thankfully acknowledged.



(S.K. Gupta)
Project Coordinator

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SUMMARY OF RESEARCH ACCOMPLISHMENTS

Survey and Characterization of Ground Water and Salt affected Soils (All Centres)

Survey and characterization of ground water and salt affected soils is an on-going activity aiming at classifying soils and waters according to the nature of problem. The characterization of soils and water should help in deciding the nature of interventions. Ground water and/or soil quality of the following districts was surveyed.

Andhra Pradesh	Nellore, Guntur, Prakasam
Haryana	Parts of Bhiwani, Mahendragarh
Karnataka	Gulbarga, Gadag
Madhya Pradesh	Mandsaur
Rajasthan	Sikar
Tamil Nadu	Perambalur, Ariyalur
Uttar Pradesh	Rae Bareli, Etawah

Changes in Ground Water Quality at Benchmark Locations (Bapatla)

EC of the tube well water varied from 1.01 to 12.7 dS/m in 2008-09 and 0.79 to 12.30 dS/m during 2009-10. The EC remained more or less the same at all locations except Machavaram where an increasing trend was recorded from 5.1 to 7.9 dS/m during 2008-09. Not much change in EC levels were observed during 2009-10.

Conjuctive Use of Alkali/ Canal Waters (Agra)

The yearly or seasonal conjunctive use strategy for canal and alkali (RSC 15 meq/l) waters for growing potato-sunflower–green manure crop rotation was assessed. It was observed that the modes where more numbers of canal water irrigations were applied, gave higher yield compared to the modes with more numbers of alkali irrigations in both the crops. In mixing modes (2 canal + 1 alkali) gave higher yield to the mixing mode (1 canal + 2 alkali). The relative yield of potato and sunflower in all alkali irrigation water over all canal irrigation were 8 and 18 per cent. The keeping quality of potato tuber in terms of weight loss with time was found better in canal irrigation than alkali water. The oil content in sunflowers was also higher in canal (42.2%) than alkali (36.3%) water irrigated crop. The alkali water irritation increased the sodicity (ESP) in the soil and recorded 23.4 after harvest of potato in 0-30 cm depth with all alkali irrigation, which further increased to 39.1 after harvest of sunflower.

Conjunctive Use of Canal and Alkali Water in Rice Based Cropping Systems (Tiruchirapalli)

A significant difference in rice grain yield was observed due to different sources of irrigation and planting methods in rice. Higher rice grain yield was recorded in canal irrigation followed by canal and alkali water in 1:1 cyclic mode. Rice irrigated with canal and alkali water in 1:1 cyclic mode recorded an increased grain yield of 8.3% and 15% over alkali water in both the years of 2008 and 2009. Amongest the method of planting, rice seedlings planted in SRI registered an increased grain yield of 1.07 and 0.94 t/ha over conventional planting (random planting) in both the years. Conjunctive use of canal water for rice and alkali water for vegetable crops recorded the highest brinjal yield of 25.3 t/ha and 22.8 t/ha during 2008 and 2009.

High RSC Water along with FYM and Gypsum in Vegetables (Hisar)

In the year 2008-09, the yield of cluster bean increased significantly with the addition of both FYM and gypsum. The highest yield of 13.07 t/ha was observed in F_2G_2 (FYM @ 20t/ha and gypsum to neutralize 100% RSC) treatment and the lowest (0.20 t/ha) was recorded in F_0G_0 (Not FYM, no gypsum) treatment. The highest yield (10.60 t/ha) of broccoli was observed in F_2G_2 treatment and the lowest (0.32 t/ha) was recorded in F_0G_0 treatment under sodic water irrigation (RSC - 11.5 meq/l). In

the year 2009-10, the highest yield of cluster bean (9.13 t/ha) was obtained in F_2G_2 treatment and the lowest (0.45 t/ha) was recorded in F_0G_0 treatment. The highest yield of broccoli (10.70 t/ha) was observed in F_2G_2 treatment and the lowest (0.33 t/ha) was recorded in F_0G_0 treatment.

In bitter gourd, the mean yield increased by 78 and 117 per cent with F_1 (FYM @ 10 t/ha) and F_2 (FYM @20 t/ha) as compared to F_o (No FYM) , respectively. The mean yield of bitter gourd increased significantly with the addition of gypsum i.e. 18 times increase in G_4 (Gypsum to neautralize 100 % RSC) as compared to G_0 (No gypsum). The mean yield of knol-khol increased from 1.91 t/ha under no gypsum to 10.68 t/ha under 100 per cent GR. Maximum yield (10.43 t/ha) of knol-khol was obtained in F_2G_4 treatment. Maximum yield (9.52 t/ha) of okra was obtained in F_2G_4 treatment. The yield increased by 18 and 22 percent with F_1 and F_2 as compared to F_0. The mean yield increased from 17.53 t/ha under no gypsum to 25.95 t/ha under 100 per cent GR. Maximum yield (27.43 t/ha) of cabbage was obtained in F_2G_4 treatment.

Management of High RSC Waters in Heavy Textured Soils (Bapatla)

Pyrites and gypsum were applied twenty five days before sowing of cluster bean. Gypsum was found to be the best in increasing the pod yield followed by pyrites, FYM, pressmud cake and aluminium sulphate over control. Phosphogypsum applied with RSC of 5 meq/l water recorded highest pod yield (371.2 g/pot) while lowest yield was recorded in control. Significant differences in pod yield were observed in pyrites treatment at varying RSC levels. Yield decreased with increasing levels of sodium in water irrespective of amendments. Similar trend followed in case of dry matter yield.

Use of Agro-chemicals for Minimizing the Alkalinity Hazards and Sustaining Crop Yield on Alkali Irrigated Soils (Kanpur)

To assess the efficacy of different amendments in reclaiming sodic water, an experiment was initiated with three amendments i.e. gypsum, pyrites and press mud. Neutralization of RSC water through dissolution of gypsum in 15 cm gypsum bed increased yields of both rice and wheat significantly as compared to untreated irrigation water. The grain yield of rice and wheat showed that application of gypsum @ 50, 100, and 150%GR were at par. Similarly, application of different doses of pyrite as well as press mud had no significant differences in grain yield of rice and wheat. The variation in average grain yield of rice (3.81 3.72 and 3.50 t/ha) and wheat (3.41, 3.36 and 2.99 t/ha) due to the application of gypsum @ 50% GR or pyrite @ 50% GR or press mud @ 5 t/ha respectively were found to be non-significant.

Drip Irrigation to Vegetables in Alkali Soil using Amended Alkali Water (Tiruchirapalli)

An experiment on the efficacy of ameliorated alkali water and drip irrigation system on vegetable crops showed that soil application of gypsum @ 50% GR significantly increased the yield of both okra and cluster bean. An increase of 12.7% in okra and 22.1% in cluster bean was recorded. Among the irrigation treatments, drip irrigation with spent wash treated water recorded the highest yield in okra and drip irrigation of gypsum bed treated water recorded highest yield in cluster bean crop. The interaction effect showed that soil application of gypsum @ 50% GR along with drip irrigation of spent wash treated water recorded the highest okra yield which was at par with soil application of gypsum @ 50% GR along with drip irrigation of gypsum bed treated water. In case of cluster bean, soil application of gypsum @ 50% GR along with drip irrigation of gypsum bed treated water recorded the highest yield which was at par with soil application of gypsum @ 50% GR along with drip irrigation with spent wash treated water.

Tolerance of Vegetables to Saline Water Irrigation under Drip and Surface Irrigation (Bikaner)

Onion yield was highest under drip with irrigation water salinity of 3.0 dS/m. Drip method was superior with 24.1% higher yield as compared to flood irrigation. The crop yield was significantly reduced at 6.0 dS/m.

Performance of Drip Irrigation System with Saline Water for Vegetable Crops (Bapatla)

The highest mean yields of okra and tomato were recorded with Best Available Water (BAW) through drip irrigation (2.82 and 7.61 t/ha) followed by 2 EC_{iw} (2.6 and 7.45 t/ha), 4 EC_{iw} (1.01 and 4.95 t/ha) and 6 EC_{iw} (0.51 and 3.11 t/ha) water, respectively during 2008-09. The salinity build-up in surface soil was 0.96 dS/m in BAW treatment followed by 2, 4 and 6 EC_{iw} treatments with 1.32, 2.44 and 3.10 dS/m, respectively. Similar trend was noticed during 2009-10 and the highest mean yields of okra, tomato and brinjal recorded were 3.78, 14.97 and 5.02 t/ha with Best Available Water (BAW) through drip irrigation followed by 2 EC_{iw} (3.49, 14.38 and 4.56 t/ha); 4 EC_{iw} (2.08, 1078 and 3.50 t/ha) and 6 EC_{iw} (1.23, 7.88 and 1.25 t/ha), respectively. The salinity build-up in surface soil was 0.22 dS/m in BAW treatment followed by 2, 4 and 6 EC_{iw} treatments with 1.27, 2.01 and 2.40 dS/m, respectively.

Performance of Pearl millet-Wheat Crop Rotation Irrigated with Sodic Water through Sprinkler System under different Depths of Irrigation (Hisar)

The study on use of sodic (RSC 12 meq/l) water through sprinkler system in pearl millet-wheat crop rotation with four levels of gypsum (0, 50%, 75% and 100% neutralization of RSC) and three irrigation depths (4, 5 and 6 cm) was carried out at Regional Research Station, Bawal in 10 m x 4m strips. In the year 2008-09, the mean grain yield of pearl millet increased by 21.7, 36.5 and 41.7 per cent with 50, 75 and 100% neutralization of RSC over control in sprinkler system, respectively. The grain yield in 5 cm and 6 cm irrigation depth increased by 13.1 and 18.5 per cent, respectively as compared to 4 cm water application. The pH of the soil decreased gradually and continuously with the addition of gypsum. The highest pH of 9.01 was recorded in G_o (no gypsum application) treatment with 6 cm irrigation whereas the lowest pH was observed in G_{100} (100 per cent neutralization of RSC) treatment with 4 cm irrigation. The mean grain yield of wheat increased by 22.9, 33.6 and 37.9 per cent in 50, 75 and 100% neutralization of RSC over control, respectively. The overall increase in grain yield of wheat in 5 and 6 cm depth of irrigation was 7.4 and 10.8 per cent, respectively, as compared to 4 cm depth. The highest pH of 9.89 was recorded in G_o treatment with 6 cm irrigation whereas the lowest pH was observed in G_{100} (100 per cent neutralization of RSC) treatment with 4 cm irrigation.

Crop Water/Salinity Production Function for Crops using Sprinkler Irrigation (Agra)

An experiment carried out during 2008-09 to 2009-10 with clusterbean-mustard crop rotation using sprinkler lines of BAW (EC_{iw} 3.6 dS/m and RSC_{iw} nil), saline (EC_{iw} 10 dS/m) and sodic (RSC_{iw} 10 meq/l) water revealed that mustard yield was affected by all the three variables i.e. moisture gradient, salinity and sodicity. In case of moisture, the grain yield increased with increase in depth of irrigation water applied from 0.74 to 3.64 cm per irrigation. Contrary to this, the grain yield declined with increase in salinity gradients in the range of 4.7 to 8.3 dS/m. However, in case of RSC, the grain yield was slightly affected in the gradient range of 1.8 to 7.8 meq/l.

Status of Flouride in Ground Water of Landu Tehsil in Nagaur District (Bikaner)

Analysis of water samples revealed that only 17.2 per cent water samples were safe for drinking in the tahsil as flouride content was more than 1.5 ppm in the remaining samples. The flouride content of water varied in between 1.0 to 8.8 mg/l whereas in soils it ranged from 0.47 to 3.8 mg/l. No visible adverse effect of flouride was seen on crops.

Strategies for Conjunctive Use of Saline and Canal Water in Cotton-Wheat Crop Rotation (Hisar)

During 2008-09, the highest seed cotton yield of 1.77 t/ha was recorded in canal irrigation followed by 2 canal (C) : 1 saline (S) cyclic irrigation. The lowest yield (1.36 t/ha) was obtained under fully saline irrigated plots. During 2009-10, same trend was observed. The lowest yield (1.75 t/ha) was obtained under all saline irrigated plot. In cotton, water productivity (146.0 kg/ha-cm) under saline water treatment increased to 239.7 kg/ha-cm under 2C:1S treatment. In wheat, the highest (4.64 t/ha) and the lowest (3.41 t/ha) grain yield were obtained during 2008-09 while during 2009-10, the highest

yield of 5.00 t/ha and the lowest 3.45 t/ha of wheat were obtained in all canal and all saline treatments respectively.

Strategies for Conjunctive Use of Saline and Canal Water in Pearl millet-Mustard Crop Rotation (Hisar)

In both the crops, the highest yield was recorded in canal followed by 2C:1S treatments during both the years. In years 2008 and 2009, the grain yield of pearl millet ranged from 2.33-3.64 and 2.89-3.89 t/ha, respectively in various irrigation treatments. The relative yields obtained under 2S:1C and all saline treatments were 73.4 and 64.0 per cent in year 2008 and 78.4 and 78.1 per cent in year 2009, respectively as compared to yield obtained in canal irrigation. During 2008-09 and 2009-10, the grain yield of mustard ranged from 2.15-2.74 and 2.25-2.99 t/ha, respectively. During 2008-09, the relative yield obtained under 1C:1S, 1S:1C, 2C:1S, 2S:1C, S:RTC, C:RTS and S treatments were 92.3, 86.1, 96.4, 83.9, 90.1, 85.0 and 78.5 per cent, respectively, whereas, in year 2009-10, relative yields were 91.6, 84.6, 95.3, 81.3, 89.6, 86.3 and 75.3 per cent, respectively.

Impact of Agra Canal Water on Ground Water Quality, Soil Properties and Crop Performance (Agra)

Agra canal and drinking water samples were collected every month from different locations of Agra canal i.e. Okhla (Delhi), Palwal (Haryana), Kosi (Mathura), Goverdhan (Mathura) and Bichpuri (Agra). Canal water is being used for irrigation for different vegetables, cereals and pulse crops. In general canal water has low salinity but due to contamination of industrial effluents and sewage water, the salinity is slightly high (1.0 to 1.5 dS/m). The heavy metals such as copper, zinc, manganese, cobalt and iron showed higher concentration than the permissible limit. SAR ranged from 1.2 to 10.2 $(mmol/l)^{1/2}$ and RSC was present only in few samples.

Assessment of Treated Sewage on Soil Properties, Crop Growth and Ground Water Quality (Agra)

The sewage water and drinking water samples were collected every month from different locations of Sewage Treatment Plant (STP) Dandhupura, district Agra which is being used for irrigation of different vegetables, cereals and pulse crops. The salinity of water ranged from 3.1 to 5.2 dS/m. BOD from 197 to 236 mg/l, bicarbonate from 427 to 1269 mg/l, chloride 49 to 524 mg/l and sulphate 96 to 1728 mg/l. Among the cations calcium ranged from 80 to 120 mg/l, magnesium 68-138 mg/l, sodium 324-731 mg/l. However, potassium ranged from 32 to 44 mg/l. SAR ranged from 5.7 to 13.8 and RSC nil to 3.8 meq/l. In water samples of STP out let, one km away from STP, submersible pump near STP and hand pump near STP, the water salinity slightly less. There was not much change in heavy metals due to water treatment.

Effect of Sea Water Intrusion on Ground Water Quality in Coastal Belt of Krishna (Bapatla)

Various villages in four locations viz., Machilipatnam, Bapatla, Nizampatnam and Kanuparthi in Coastal Region of Krishna Zone of Andhra Pradesh near the sea were earmarked by using GPS. The soil samples were collected at 5, 10, 15 and 20 kms away from the sea. The pH values ranged from 7.00 to 9.10 and 6.98 to 8.41 and EC values from 0.57 to 12.90 and 0.19 to 16.94 for June and December 2009, respectively. The observations on intrusion prospects would be made as soon as more data are in hand.

Survey and Minimization of Adverse Effects of Nitrate in Ground Water (Bapatla)

Sixteen groundwater samples were collected from heavily fertilized areas of Guntur and Krishna districts of Andhra Pradesh. In Guntur district, the NO_3 content ranged from 0.9 to 22.3 ppm with 44 percent of samples showing above permissible limit of 15 ppm, while in Krishna district it ranged from 1.1 to 10.8 ppm. SAR was less than 10 $(mmol/l)^{½}$ in both the districts while RSC was 0.0 to 4.2 meq/l in Guntur district and in Krishna district within 2.5 meq/l.

Survey and Minimization of Adverse Effects of Fluoride in Ground Water (Bapatla)

Sixty two groundwater samples were collected from Prakasam district covering 16 Mandals in Ongole division and analysed for pH, EC, cations and anions. The EC ranged from 0.45 to 11.13 dS/m, pH ranged from 7.06 to 9.10, CO_3 ranged from 0 to 5 meq/l, HCO_3 ranged from 1.3 to 13.6 meq/l , while chlorides ranged from 1.2 to 68.0 meq/l. Chloride was dominant among anions. Among cations, Na was dominant with a range of 1.0 to 108.2 meq/l followed by Mg with 1.2 to 16.8 meq/l and Ca with 0.8 to 7.2 meq/l. The fluoride content ranged from 0.75–4.5 ppm, the highest value of 4.5 ppm was recorded in water of Sankarapuram of Mundlamuru Mandal, while the lowest value of 0.75 ppm was recorded in Dharmavaram village of Addanki Mandal. The fluoride content was beyond permissible limit of 1.5 ppm in about 69 per cent of water samples making these unfit for drinking purposes without defluoridation.

Response of Crops to Varying levels of Salinity and Irrigation under Sprinkler Irrigation (Bikaner)

In the zone with saline water (EC 4.2 dS/m), the total depth of water applied ranged from 19.40 to 42.91 cm (7 irrigation) and yield of wheat crop was in the range of 0.49 to 1.85 t/ha. It was found that yield level increased till the total water applied was around 34 cm, thereafter it started decreasing. In the BAW zone, the yield increased linearly upto a total depth of 38 cm, thereafter, it started declining. From the results it can be recommended that the total depth of water applied should be around 40 cm divided in 7 irrigations when canal water is used under sprinkler irrigation system. The pod yield of groundnut ranged between 0.20 to 0.36 t/ha depending upon the quantity of water applied under saline water zone. At irrigation water salinity of 3.0 dS/m, 50% reduction in yield was observed at a total depth of 60 cm of water applied.

Optimization of Zinc Requirement of Wheat Crop Irrigated with Sodic Water (Hisar)

The study on application of Zn to wheat crop irrigated with sodic water in relation to different doses of gypsum (0, 25, 50, 75 and 100% neutralization of RSC) was initiated at Village Bhurjat, District Mahendragarh from 2007-08. In the year 2008-09, the mean yield increased by 140, 235, 304 and 349 per cent, respectively, in G_{25}, G_{50}, G_{75} and G_{100} treatments as compared to control. The application of Zn @ 25 and 50 kg/ha resulted in 10 and 16.9 per cent increase in yield, respectively, as compared to control. In year 2009-10, the mean yield increased by 91.45, 145.31, 201.19 and 270.33 per cent, respectively, in G_{25}, G_{50}, G_{75} and G_{100} treatments as compared to control. The application of Zn @ 25 and 50 kg/ha resulted in 16.2 and 27.5 per cent increase in yield, respectively, as compared to control.

Studies on Long- Term Effect of Sewage Irrigation on Soil and Crops (Tiruchirapalli)

Monitoring of the sewage water irrigated fields, revealed that soil samples contained high amount of Pb (2.45 and 2.01 ppm) compared to Ni and Cd during 2008 and 2009 respectively. Similarly in the plant samples, the Pb accumulation was found to be more in the grain compared to other plant parts.

Tolerance of Vegetable Crops to Saline Irrigation under Drip and Surface Irrigation System (Agra)

The experiment was carried out in micro-plots with capsicum-okra crop rotation. The EC_{iw} 4 and 8 dS/m reduced the average fruit yield of capsicum by 35.0 and 46.7% in drip irrigation and 39.7 and 50.6% in surface irrigation, respectively. The average okra fruit yield reduced by 53.5 and 75.9% in drip irrigation and 71.5 and 99.9% in surface irrigation in EC_{iw} 4 and 8 dS/m over control, respectively. The water use efficiency was higher in drip irrigation than surface irrigation. In okra, the water use efficiency in control, EC_{iw} 4 and 8 dS/m was 203.7, 101.1 and 53.0 kg/ha-cm in drip irrigation and 138.8, 41.5 and 0.01 kg/ha-cm in surface irrigation system, respectively.

Drain Water Usage and Management Strategies of Nallamada Drain (Bapatla)

The study was conducted on Nallamada drain. The data revealed that the EC (drain water) was ranging from 1.08 to 1.92 dS/m during August, 2009 and an increasing trend was noticed from

November, 2009 to March, 2010. The drain water was fit for irrigation to crops like maize, sorghum, sunhemp etc. The performance of rice crop was tested in saline soils of Kondapaturu with leaching using Nallamada drain waters. With leaching activity, the soil salinity reduced from 28.0 to 1.0 dS/m, 32.0 to 3.3 dS/m and 30.0 to 4.1 dS/m and grain yields recorded were 3.5 t/ha (NLR 145) and 5.63 t/ha (BPT 2270).

Organic input management options with saline water irrigation for sustaining productivity of high value crops (Karnal)

Results of experiment on sesame and fennel irrigated with saline water showed that sesame yield is influenced by high salinity as compared to low salinity water. The application of organic inputs viz., farmyard manure, vermicompost and neem cake manure produced higher seed yield of sesame as compared to inorganic treatments. The seed yield of fennel differed non-significantly under low and high saline water irrigation during first year but in second significant difference was observed among low and high saline water irrigation. Highest fennel seed yield (1.21 t/ha) was observed under 50% recommended doses of organic inputs viz., farm yard manure + vermicompost. The recommendations would be framed at the completion of the project in due course of time.

Survey and Characterization of Sharada Sahayak Canal Area for Soil Quality (Kanpur)

The soil samples collected from the villages adjoining to Hydergarh road, Tiwari Purwa, Amba Block and Matoli Ka Purwa (A-left bank) and Vinayak Pur, Bargadhika Purwa, Kundoli (Kaithal Khurd), Pahadpur, Harchandpur, Aframau, Raghunathpur (B-right bank) in Tehsils of Maharajganj, Raebarelly and Unchahar showed that the soils occurring in the vinicity of Ganga, which forms the southern boundary of the district, mainly in the village Bacharawa and Shivgarh showed the nature of the alluvial deposits varied from year to year depending upon the intensity of floods and the velocity of water. The depth-wise soil samples do not show any sign of pedogenic development. Some fields were waterlogged and the performance of crop was poor in most of the fields. Soils are very hard and compact when dry and become sticky when moist. The soils are neutral in reaction with the exception of surface layer and are poor in organic matter content. Total water soluble salts are medium and mainly comprise of bicarbonate and chloride of sodium. Kankar pan was also observed at a depth of 60 to 90 cm at few places. Further analysis of soil and water samples is in progress.

Investigations on Potential of Micro Irrigation for Vegetables for Saline Soils (Gangawati)

Drip irrigation at 1.2 ET recorded highest yield as compared to other irrigation levels in cabbage and beetroot. Amongst surface irrigation, highest yield was observed in case of 1.2 ET. Performance of crop was better in salinity level of less than 4 dS/m as compared to higher levels. Drip irrigation at 1.2 ET under salinity level-I is the best among all other treatments.

Reclamation of Abandoned Aqua Ponds (Bapatla)

Rice grain yields at fourteen locations in Kothapalem ranged from 0.13 to 6.0 t/ha during 2008-09. Low yields were recorded in some locations due to poor establishment of seedlings and high salinity at initial stages of crop growth. In 2009-10, rice grain yields ranged from 3.8 to 5.6 t/ha. During both the years, the EC of the soils decreased from 64.0 to 25.1 dS/m to 14.1 to 8.51 dS/m, respectively.

Effect of Set Furrow Methods of Gypsum Application and Textural Modification on Soil Reclamation and Crop Performance (Indore)

A field experiment was initiated on methods of gypsum application and effect of modification in texture on growth and yield of cotton crop. Highest seed cotton yield was recorded when 50 tons of sand along with gypsum was incorporated to soil in a set furrow system and was followed by the treatment where only gypsum was incorporated in set furrow. The treatment where gypsum + sand @ 50 ton was applied in plough layer ranked third in terms of seed cotton yield.

Influence of Spent Wash and Spent Wash Vermicompost on Reclamation of Sodic Soils (Indore)

A field experiment was initiated at Indore during the year 2003-04 on comparative performance of gypsum, spent wash and spent wash vermi-compost application on reclamation of a sodic Vertisols and its effect on growth and yield of rice-wheat cropping sequence. Treatments included control, single or combined application of FYM, gypsum @ 75% of GR and vermi-compost and spent wash (2.5, 5.0 and 10.0 cm). The rice and wheat grain and straw yield were significantly affected by different amendments. The highest grain and straw yield was recorded with the application of spent wash @ 10.0 cm which was statistically at par with 5 cm. The uptake of Ca, Mg and K by grain and straw of wheat was significantly affected due to the application of different amendments. The highest Ca uptake by grain and K uptake by straw was observed at 10.0 cm spent wash application however it was at par with 5 cm. The application of amendments decreased the EC_e and ESP of soil after harvest of wheat crop.

Response of Crops to Chemical and Organic Amendments in Alkali Vertisols (Indore)

Application of FYM @ 10 t/ha with 50% of gypsum requirement or FYM @ 10 t/ha with 75% of gypsum requirement or vermicompost @ 2.5 t/ha with 50% of gypsum requirement and vermicompost @ 2.5 t/ha with 75% of gypsum requirement to sunflower and cotton resulted in higher yield and improved the soil physical condition.

Effect of Long-term Application of Organic/Green Manures on Sodic Vertisols (Indore)

The experiment was initiated in 2005-06 at Indore to observe the effect of green manuring on soil properties and crop yield in an alkali soil. Four treatments (i.e. control, FYM @ 10 t/ha, sunhemp and *dhaincha* green manuring crops) were tested at four soil ESP levels (25, 35, 45 and 50). The yield of both the crops decreased with increase in soil ESP during both the years. The maximum yield of paddy (2.30 and 2.41 t/ha) and wheat (3.40 and 2.82 t/ha) was recorded at soil ESP of 25 during 2008-09 and 2009-10 respectively. Among various treatments incorporation of *dhaincha* gave highest yield and lowest was observed in control plot for both the crops.

Studies on Performance of Crops after Tree Harvesting in Alkali Soils Environment (Indore)

The experiment was conducted at Indore to test the crop performance after removal of tree species in alkali environment after 14 years of plantation. The data revealed that the maximum grain yield of sorghum (1.73 & 1.50 t/ha) and wheat (3.17 & 3.06 t/ha) was obtained where *Azadirachta indica* was planted followed by *Prosopis juliflora* in the year 2008-09 and 2009-10 respectively.

Effect of Switching Over to Upland Cropping Sequence on Resodification and Sustainability of Crop Yield in Reclaimed Sodic Soil under Constrained Water Supply Conditions (Kanpur)

Continuous cropping of the reclaimed land is a pre-requisite to sustain the process of reclamation once initiated with application of gypsum. To see the effect of switching over to low water requiring crops and green manuring on reclamation process, an experiment was initiated. Yield data revealed beneficial effect of gypsum application and showed significant difference in various treatments over control. Studies on residual effect of gypsum (applied once in 1997) revealed significant increase in grain and straw/stock yield of rice, wheat, sorghum and mustard in cropping sequence of rice-wheat, fallow-wheat and sorghum-mustard. In plots incorporated with green manure in fallow-wheat cropping sequence, higher grain and straw yield of wheat were obtained in comparison to rice-wheat cropping sequence but yield differences were marginal. Application of gypsum and green manure decreased soil pH, EC and ESP respectively.

Monitoring and Evaluation of Large Scale Subsurfcae Drainage Projects in Haryana (Karnal)

The first phase of the project was completed. The projects at Beri and Dadri were completed while projects in Sirsa, Fatehabad and Sonepat were in progress. Final results on Beri and Dadri projects

revealed a significant decline in soil salinity and a cosequent increase in rice-wheat yields at both the sites. A desk study revealed that under the prevailing water table conditions in the Beri area, as much as 75% of the cost of pumping could be saved with gravity-cum-pumped outlet, if technically feasible to construct. With such a system, there would be no need to pump water for water and salt balance as this requirement could be fully met with the gravity flow. Pumping for irrigation purpose would only be needed for which farmers have no hesitation in investing on pump and operational cost. Application of WaSim model revealed that there should be no build-up of soil salinity on a long-term basis. Salinity build-up on year to year basis might occur but it could be taken care off by applying a heavy pre-sowing irrigation on short-term basis and over the long-term, above normal rainfall would take care of the residual build-up of soil salinity. It could be concluded that WaSim Model could be used in monitoring and evaluation of various management options that could be applied to manage drained lands to get maximum advantage of land drainage.

Subsurface Drainage for Heavy Soils of Maharashtra and Karnataka (Karnal)

Coordinating Unit of AICRP project is providing technical guidance to projects in Maharashtra /Karnataka being implemented in non-commanded lift irrigation schemes with funding from Ministry of Rural Development and RKVY. In Ugar (Karanatka), it emerged that open main drains being constructed were posing severe construction problems and a piped main drain might be constructed to overcome these problems. The feasibility study revealed that it could be implemented provided a sufficient fall between the laterals / sub collectors and mains could be ensured. Technical problem of *Prosopis* roots blocking the pipes was also examined and appropriate solutions proposed. It was observed that farmers are willing to invest on individual drainage projects provided there are no post drainage operational expenses. As such, individual ptrojects could come up in large number provided gravity outlets are feasible in the area.

Investigations, Design and Installation of Subsurface Drainage Systems (Bapatla)

Monitoring the performance of drainage system for a period of 7 years from 2002-03 to 2008-09 indicated that the average discharge from the pipe drains laid at 30 m spacing was the highest in all the years when compared to the pipe drains laid at 60 m spacing. With the functioning of subsurface drainage system, a total of 184.4 tons of salts were leached out through the drainage system during the period of 7 years with a mean of 24.7 tons per ha. The soil salinity reduced to 1.7 to 8.4 dS/m at the end of 7th year with a mean salinity of 3.1 dS/ m, *Kharif* paddy crop yield improved from 1.8 t/ha to 6.75 t/ha with a mean value of 5.8 t/ha. Also paddy straw yield improved and 2nd crop could be established from 2nd year onwards. The economic analysis under mono-crop system revelaed that the net present worth of the system is 71106/-, B:C ratio is 1.24 and internal rate of return is 39.07 per cent.

Monitoring Salinity Hazards in Vegetables under Drip Fertigation with Saline Water in Vertisols (Indore)

The study was carried out during 2008-10 at Indore to monitor the effect of drip fertigation with marginally saline water on salinity and economics of horticultural crops grown in Vertisols at farmer's field of Bagda Khurd village of Khargone district, Madhya Pradesh. Data indicated that in case of tomato (Abhinav), average values of EC were 0.40, 0.46, 0.55, 0.64, 0.69 and 0.35 dS/m at sampling point on-dripper for 1st, 2nd, 3^{rd,} 4th, 5th, and 6th samplings, respectively. Similar trend was observed with all the crops grown. EC increased as sampling point moved away from the drippers i.e. side of the ridge and between drippers. The minimum values were recorded at sampling point on drippers. The difference between maximum and minimum average value of EC were 0.29 dS/m, 0.41 dS/m, 0.50 dS/m and 0.43 dS/m on the sampling locations viz. on drippers, between two drippers, side of the ridge, side of dripper, respectively. Growing horticultural crops with drip fertigation using marginally saline well water in Vertisols is a feasible and economically viable venture as indicated by B:C ratios which were greater than 1 in case of all crops. The highest B:C ratio of 3.50 was obtained in garlic followed by bitter gourd crop as 3.11. The lowest was obtained in

tomato as 2.16. The highest WUE was obtained as 5.47 q/ha-cm in tomato and lowest in the garlic as 2.37 q/ha- cm.

Effect of Doses and Frequency of Gypsum application on Crop and Soils in Sodic Environment (Indore)

The experiment was initiated in 2005-06 to study the effect of doses and frequency of gypsum application on soil properties and crop performance in sodic soil. The lowest ESP was observed with gypsum application @ 100 % GR followed by gypsum application @ 75% GR + FYM @ 5 t/ha. The grain yield of paddy and wheat increased significantly with doses of gypsum application over FYM application @ 5 t/ha. Frequency of gypsum application showed significant impact on grain yield of paddy as well as wheat as gypsum was reapplied after 3 years as per treatments. However, interaction of doses and frequency were non-significant. The maximum average grain yield of paddy (2.17 and 2.13 t/ha) and wheat (4.63 and 4.52 t/ha) was recorded when gypsum was applied @ 75% GR along with FYM @ 5 t/ha in the year 2008-09 and 2009-10, respectively.

Efficacy of Phosphogypsum as an Amendment for Alkali Soil (Kanpur)

On the basis of the first year experimentation, the yield data of rice and wheat indicated that there was an increase in yield with the use of amendment over untreated control. The highest grain yield of rice and wheat was recorded as 3.53 and 3.15 t/ha with the application of phosphogypsum which was 4.77 and 4.69 percent higher in comparison to gypsum respectively. The crop irrigated with RSC water through 15 cm gypsum/ phosphogypsum beds was found superior than the soil application of amendments.

Evaluation of Integrated Resource Conservation Technology for Rice-Wheat Cropping System under Reclaimed Sodic Soil (Kanpur)

Continuous cropping of the reclaimed land is a pre-requisite to sustain the process of reclamation once initiated with application of gypsum. To see the effect of switching over to low water requiring crop s and green manuring on reclamation process, an experiment was initiated. Yield data revealed beneficial effect of gypsum application and showed significant difference in various treatments over control. Studies on residual effect of gypsum (applied once in 1997) revealed significant increase in grain and straw/stock yield of rice, wheat, sorghum and mustard in cropping sequence of rice-wheat, fallow-wheat and sorghum-mustard. Plots are incorporated with green manuring in fallow-wheat cropping sequence, higher grain and straw yield of wheat were obtained in comparison to rice-wheat cropping sequence but yield differences were marginal. Application of gypsum and green manure decreased soil pH, EC and ESP respectively.

Tolerance of *Ber* to Saline Irrigation (Bikaner)

The maximum average yield (43.6 kg/plant) of *ber* was obtained in treatment 0.8 PE + plastic mulch with best available water (BAW) as well as saline water (EC_{iw} 8.0 dS/m). No significant difference was observed at 0.8 PE + mulch with BAW and saline water. It is concluded that 0.8 PE irrigation level yielded maximum production with BAW and saline water.

Tolerance of Fruit Trees to Saline Irrigation under Drip and Surface Irrigation System (Agra)

The salinity tolerance of pomegranate and guava fruits was assessed under different saline irrigation, scheduling and methods. The salinity levels were BAW, EC_{iw} 8 and 12 dS/m for surface and drip irrigation systems. The irrigation scheduling in terms of ET were 0.5 and 1.0 for surface and 0.5, 0.75 and 1.0 for drip system. At ET 1.0, significantly higher plant height and girth was observed than ET 0.75 and ET 0.5 in pomegranate and guava. The increasing salinity levels decreased the plant height and stem girth. The fruit yield of pomegranate was significantly higher (11.2%) in drip than surface system. At ET 0.75 and 0.5, the yield decreased by 12.3 and 29.5% as compared to ET 1.0.

Methods of Irrigation and Quality of Water on Performance of Fruit trees in Sodic Environment (Indore)

A field experiment was carried out at Indore to study the effect of irrigation methods and quality of irrigation water on performance of some fruit plants on sodic black soil. The saplings of sapota (Kalipatti), ber (Deshi), pomegranate (Ganesh) and drumstick (Coimbatore-1) were transplanted on 28rth July 2005, 1st August 2005, 3rd September 2005 and February, 2006 respectively at 3 x 3 m grid. Three irrigation systems (viz. Check basin, drip and embedded 110 mm diameter perforated PVC pipe of length 40 cm). Two qualities of water (normal and diluted distillery waste water) were applied in May, 2006.

There was 45 and 34 per cent irrigation water saving in case of embedded pipe and drip irrigation, respectively, over check basin irrigation. The data indicated that better growth in terms of girth and height was observed in embedded pipe and drip methods of irrigation as compared to check basin in all the fruit plants. For example, in ber (*Ziziphus zuzuba*), changes in girth as 5.9, 9.4, 10.6 cm and 7.6, 12.3, 12.1 cm and in height as 120.7, 163.8, 145.5 cm and 172.1, 210.1, 200.6 cm were observed during the year 2008 -09 cm in case of check basin, embedded pipe and drip irrigation methods, respectively, with the best available water and diluted spent wash application.

Evaluation of the Performance of Medicinal and Aromatic Plants in Saline Vertisols (Gangawati)

Among the crops tested, vetiver was found to be relatively more salt-tolerant with the EC_t value of about 6.00 dS/m. Kamaksturi and shatavari could tolerate EC of 5.38 dS/m and 4.05 dS/m respectively.

Influence of ESP on Active Ingredient of Medicinal Plants in Sodic Vertisols (Indore)

A field experiment was conducted at Indore on sodic Vertisols to assess the tolerance of medicinal plants to soil ESP. The planting / sowing of babchi, muskdana and sadabahar was carried out at the onset of monsoon. The survival of babchi and sadabahar was > 50 % up to ESP 35 whereas survival of muskdana was <50% even at ESP level 35. The seed yield of isabgol and chandrasur significantly decreased with increasing levels of ESP. The highest seed yield of isabgol (0.88 t/ha) and chandrasur (0.987 t/ha) was recorded at ESP 25. The lowest seed yield of isabgol and chandrasur was obtained at ESP 55. The reduction in seed yield of isabgol and chandrasur was more than 50% beyond ESP 35. Both the crops were sensitive to higher levels of soil ESP.

Evaluation of *Jatropha curcas* in Alkali Soils under Irrigated Condition (Tiruchirapalli)

The biometric observation at 12th and 18th months after plantation revealed that the main plot treatments viz., different spacing did not significantly influence the plant height and number of branches of *Jatropha* plant. Among the sub-plot treatments, spot amelioration with distillery spent wash (DSW) @ 150 ml/kg of excavated soil recorded the maximum plant height of 144.7 cm which was at par with the treatment receiving combined application of DSW (@ 75 m1/kg of excavated soil) and 25% GR and application of gypsum @ 50% GR.

Effect of Salinity on Growth and Yield of Medicinal Plants (Bapatla)

The fresh biomass yields of the three medicinal plants namely *Aloe Vera, Mentha Spicata and Solanum Nigrum* were at par in BAW and saline irrigation water of 6 dS/m indicating that these crops could be grown with saline water of 6 dS/m.

Screening of Elite Varieties of Crops for Cultivation under Irrigation with Poor Quality Water (Hisar)

At Hisar, during 2008-09 and 2009-10, the mean seed cotton yield of H-1117 and H-1236 were significantly higher than other genotypes. The mean wheat grain yield of WH-1084 and WH-1107

were significantly higher than other genotypes. Under IVT trial, the genotypes CSCN-09-1 of mustard gave the maximum yield (184 g/m^2) followed by CSCN-09-12 (169 g/m^2) at EC_{iw} of 7.5 dS/m. Under AVT2 trial, the genotypes CSCN-09-15 and CSCN-09-16 gave the maximum yield (218 g/m^2) followed by CSCN-09-18 (213 g/m^2) at EC_{iw} of 7.5 dS/m. The physiological traits that contributed towards the better plant growth in these genotypes were studied and further correlated to their higher yield potential.

Screening of Mustard Cultivars for Saline Irrigation (Agra)

In AVT-I trial, the highest yield was recorded in CSCN-08-16 (2.35 t/ha) and in AVT-II trial in CSCN-08-18 (1.20 t/ha) during 2008-09. During 2009+-10, in AVT-I, the highest yield was recorded in CSCN-09-14 (1.70 t/ha) and in IVT (2.46 t/ha) in CSCN-09-12.

Screening of Mustard Genotypes under Saline Water Irrigation (Bikaner)

During 2008-09, it was observed that amongst IVT genotypes CSCN-13 produced higher seed yield as compared to other genotypes and in AVT CSCN-18 produced higher seed yield and number of siliqua per plant. During 2009-10 in IVT, CSCN-8 produced higher seed yield followed by CSCN-4 and CSCN-8, whereas in AVT, CSCN-15 produced higher seed yield as well as bolder seeds.

Performance of different Varieties of Mustard under Alkali Condition (Kanpur)

The performance of twenty one (2008-09) and eighteen varieties/genotypes (2009-10) of mustard was evaluated at sodicity level of 41.5/ 42.0 ESP respectively. The seed yield of genotype varied from 0.55 t/ha (CSCN 08-12) to 1.23 t/ha (CSCN 08-08) and 0.62 t/ha (CSCN 09-10) to 1.62 t/ha (CSCN 09-12) during 2008-09 and 2009-10 respectively. The reports would be sent to the concerned quarter in due course of time.

Screening of Crop Varieties for Salt Tolerance in Maize and Bengal gram (Bapatla)

Four maize hybrids were screened for different levels of EC_{iw} viz., Best Available Water (BAW), 2, 4, 6, 8 and 10 EC_{iw}. The data revealed that among different hybrids, 30V92 recorded highest (76.7%) germination followed by DH-117 (76.2%), Sandhya (61.7%) and Suvarna (59.8%). Among different levels of EC_{iw}, highest per cent was noted at BAW (95.3%) while lowest per cent was at 10 EC_{iw} (39.8%). The Bengal gram variety JG-11, which occupied large area in Prakasam, Guntur and Nellore districts was also tested for germination to saline water. The data indicated that the germination was 92% in BAW followed by 2 EC_{iw} (82%), 4 EC_{iw} (75%), 6 EC_{iw} (68%), 8 EC_{iw} (59%) and 10 EC_{iw} (42%).

Tolerance of Cotton Varieties to Saline Irrigation under Drip System (Agra)

Seed cotton yield was 42% higher in drip method as compared to flood method of irrigation. Seed cotton yield under saline (3 dS/m) and canal water was at par. The Bt cotton was found significantly superior than other varieties. The Bt cotton variety and RST-9 produced taller plants as compared to F846 and RG-8. Number of bolls per plant and boll size was recorded higher in Bt cotton followed by RST-9. The lowest value of these parameters was recorded in variety RG-8.

Evaluation of different Crops for their Sodicity Tolerance (Tiruchirapalli)

Green gram varieties (VBN2, CO 6 and CO 7) and maize varieties (CO 1, COHM5 and C818) were tested for their tolerance to sodicity levels during 2008-2009 and 2009-2010.The results revealed that among the different ESP levels tested, ESP 9.2/9.0 recorded the highest grain yield of 521 and 495 kg/ha compared to other levels of ESP during 2008 and 2009, respectively. Green gram variety CO 6 recorded significantly higher yield during 2008 (428 kg/ha) and 2009 (407 kg/ha) than other varieties. Among the maize varieties and hybrids tested, the hybrid C818 recorded the maximum yield of 3856 and 3514 kg/ha both during 2009 and 2010, respectively. The hybrid COHM5 recorded lowest yield of 1754 kg/ha (at ESP 9) and 1412 kg/ha (at ESP level 10) during 2009 and 2010, respectively. For

both green gram and maize varieties and hybrids the highest mean yield was registered only at low ESP levels. As the ESP levels increased there was significant yield reduction in both green gram and maize varieties and hybrids.

At all ESP levels, the highest Na/K ratio was found in roots of green gram varieties and stalks of maize varieties and hybrids and the ratio increased with increasing ESP levels. The plant height and number of pods per plant for green gram varieties were higher at low ESP level compared to higher ESP levels. In maize varieties and hybrids also the plant growth and yield parameters viz., plant height, cob length and no. of grain, lines per cob recorded higher values at low ESP level than at higher ESP levels.

ORP on Improvisation and Demonstration of Reclamation Technologies for Black Alkali Soils (Bapatla)

The experiment was conducted in farmers' fields at five locations during 2008-09 and three locations in 2009-10 in Prakasam district of Andhra Pradesh. Application of gypsum along with $ZnSO_4$ @ 50 kg/ha increased rice grain yield (3.97 t/ha) over control during 2008-09. Similar increase was observed during 2009-10. The per cent increase ranged from 19.5–29.4 and 17.8 to 45.4, respectively in the two years.

ORP on Use of Poor Quality Ground Water at Farmers Field (Agra)

In alkali water (RSC 6.2–12.0 meq/l), the pearl millet was sown with gypsum @ 50% GR and compared with control. The yield increased by 13% with the application of gypsum as compared to control. However, the cotton sown on beds had higher yield by 13.1% over flat method of sowing. In *rabi* season the improvement in wheat yield ranged from 6.1 to 11.3% with an average increase of 8% in those fields where gypsum was incorporated during *kharif*. The wheat yield increased by 6 - 7% in flat sowing while in bed sowing irrigation water could be saved by 25- 30% as compared to flat sowing.

Skimming Well and Alternative Technologies to Develop Water Resources in Coastal Sandy Soils (Bapatla)

Ninety two skimming wells have so far been installed covering an area of 198 ha in twenty five villages in Prakasam, Guntur and West Godavari districts of Andhra Pradesh including 6 drinking water wells. The water table depth varied from 1.39 to 2.04 m at Bapatla and ground level to 1.79 m at Timmareddypalem. The EC of skimming well waters at Bapatla and Timmareddypalem varied from 0.16 to 0.54 dS/m and 0.77 to 0.90 dS/m, respectively during 2008-09.

Even under adverse situation of increase in costs and decrease in returns to the tune of 5 per cent each, the farmers will be benefitted with skimming well with collectors, as indicated by NPW, B:C ratio and IRR at 52629, 2.01 and 33 per cent for the life of the structure assumed as 25 years. The studies revealed that the improved fresh water skimming techniques have promising prospects to sustain crop production and ensure potable water supply along the coastal belts.

Effect of Gypsum Application on Crop Production and Soil Environment at Farmers' Fields (Indore)

The demonstrations were carried out at farmer's fields in two villages of Indore and Khargone districts of Malwa and Nimar agro-climatic zones to demonstrate the technology of reclaiming salt affected soils with soybean – wheat cropping sequence (Indore) and cotton crop (Khargone). Application of gypsum significantly increased seed and straw yield of soybean as well as grain and straw yield of wheat over control. The application of gypsum (@ 50 and 75% GR) significantly increased seed cotton yield as compared to control and 25% GR. However, the differences between 50% GR and 75% GR were statistically non-significant.

INTRODUCTION

The All India Coordinated Project for Research on Use of Saline Water in Agriculture was first sanctioned during the Fourth Five Year Plan under the aegis of Indian Council of Agricultural Research, New Delhi at four research centers namely Agra, Bapatla, Dharwad and Nagpur to undertake researches on saline water use for semi–arid areas with light textured soils, arid areas of black soils region, coastal areas and on the utilization of sewage water respectively. During the Fifth Five Year Plan, the work of the project continued at the above four centers. In the Sixth Five Year Plan, four centers namely Kanpur, Indore, Jobner and Pali earlier associated with AICRP on Water Management and Soil Salinity were transferred to this Project whereas the Nagpur Center was dissociated. As the mandate of the Kanpur and Indore centers included reclamation and management of heavy textured alkali soils of alluvial and black soil regions, the Project was redesignated as All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture. Two of its centers located at Dharwad and Jobner were shifted to Gangawati (w.e.f. 1.4.1989) and Bikaner (w.e.f. 1.4.1990) respectively to work right at the locations having large chunks of land afflicted with salinity problems. During the Seventh Plan, the project continued at the above locations. During Eighth Five Year Plan, two new centers at Hisar and Tiruchirapalli were added. These Centers started functioning from 1st January 1995 and 1997 respectively. During the Tenth Plan, the project continued with the same centers with an outlay of Rs. 1090.00 lakh. During the Eleventh Plan, Project continued with an outlay of Rs. 2125.15 lakhs with ICAR Share of Rs. 1695.63 lakhs at the following centers with the Coordinating Unit at Central Soil Salinity Research Institute, Karnal.

Cooperating Centres with Addresses

1. R.B.S. College of Agriculture, Bichpuri, Agra–283 105 (Uttar Pradesh)
2. Regional Research Station, Acharya N.G. Ranga Agricultural University, Bapatla–522 101 (Andhra Pradesh)
3. S.K. Rajasthan Agricultural University, Bikaner–334 002 (Rajasthan)
4. Agricultural Research Station, University of Agricultural Sciences, Gangawati, Koppal–583 227 (Karnataka)
5. Department of Soils, C.C.S. Haryana Agricultural University, Hisar- 125 004 (Haryana)
6. Agricultural College, M.V.R.S. Krishi Vishwa Vidyalaya, Indore-452 001 (Madhya Pradesh)
7. Agriculture College, C.S. Azad University of Agriculture & Technology, Kanpur–208 002 (Uttar Pradesh)
8. A.D. Agriculture College & Research Institute, Tamil Nadu Agricultural University, Tiruchirapalli –620 009 (Tamil Nadu)

However, with the establishment of Agricultural universities at Gwalior in Madhya Pradesh and Raichur in Karnataka, the administrative control of the centres at Indore and Gangawati has been transferred to these respective universities.

XI Plan Mandate

- Survey and characterization of salt affected soils and ground water quality in major irrigation commands.
- Evaluate the effects of poor quality waters on soils and crops.
- Develop standards/guidelines for the assessment of quality of irrigation waters.
- Develop management practices to utilize waters having high salinity/alkalinity and toxic ions.
- Develop and test technology for the conjunctive use of poor quality waters in different agro–ecological zones/major irrigation commands.

- Develop alternate land use strategies for salt affected soils (Agro-forestry).
- Screen crop cultivars and tree species appropriate to salinity and alkalinity soil conditions.

Within the mandated tasks, following activities were initiated or strengthened at various centers during XI plan.

- Generation of data bases on salt affected soils and poor quality waters
- Environmental impacts of irrigation and agriculture in irrigation commands and at benchmark sites
- Micro-irrigation system for saline water use to high value crops; to develop crop production functions with improved irrigation techniques
- Crop production with polluted (Agra Canal) and toxic water and bio-remediation strategies
- Water quality limits for new cropping pattern
- Development of new sources of fresh water for conjunctive use (Rainwater harvesting) and groundwater recharge
- Pollution of surface and ground water including modelling
- Reclamation and management of salt affected soils and water in Nagaur area in Rajasthan
- Management of abandoned aquaculture ponds
- Seawater intrusion and modelling
- Extension of Doruvu technology and test cheaper alternatives for skimming of fresh water floating on saline water
- Survey and characterization of toxic elements in coastal groundwater
- Resodification of reclaimed alkali lands and comparative performance of various amendments
- Dry land reclamation technologies
- Land drainage of waterlogged saline lands for cost minimization
- Conservation agriculture/multi-enterprise agriculture/ multiple use of water
- Alternate land management including cultivation of unconventional petro-plants, medicinal, aromatic and plants of industrial application

Finance

The Eleventh Five Year Plan (2007–2012) was sanctioned by the Council vide letter N. 9-2/2007/IA-II dated 20.10.2008 with an outlay of Rs. 2125.15 lakhs (ICAR Share Rs. 1695.63). The budget head and center wise statement of expenditure for 2008–2009 and 2009–10 is given in the annexure G 6.

RESEARCH ACCOMPLISHMENTS

A. USE OF SALINE WATER IN AGRICULTURE

- Survey and Characterization of Ground Waters for Irrigation
- Studies at Benchmark Locations in Guntur district to monitor the Changes in Ground Water Quality and Soil Properties (Bapatla)
- Effect of Saline Water Irrigation on Crop Yield and Soil Properties (Agra)
- Conjunctive Use of Alkali/Canal Waters (Agra)
- Conjunctive Use of Canal and Alkali Water in Rice Based Cropping Systems (Trichy)
- Effect of High RSC Water along with FYM and Gypsum in Vegetables (Hisar)
- Management of High RSC Waters in Heavy Textured Soils (Bapatla)
- Use of Agro-Chemicals for Minimizing the Alkalinity Hazards and Sustaining Crop Yield on Alkali Irrigated Soil (Kanpur)
- Drip Irrigation to Vegetables in Alkali Soil using Amended Alkali Water (Trichy)
- Tolerance of Vegetables to Saline Water under Drip and Surface Methods of Irrigation (Bikaner)
- Performance of Micro (Drip) Irrigation System with Saline Water for Vegetable Crops (Bapatla)
- Performance of Pearl millet-Wheat Crop Rotation Irrigated with Sodic Water through Sprinkler System under different Depths of Irrigation (Hisar)
- Crop Water/Salinity Production Functions for different Crops using Sprinkler Irrigation (Agra)
- Status of Fluoride in Underground Irrigation Water of Ladnu Tehsil in Nagaur District and its Effect on Soil Properties and Crops (Bikaner)
- Strategies for Conjunctive Use of Saline and Canal Water in Cotton-Wheat Crop Rotation (Hisar)
- Strategies for Conjunctive Use of Saline and Canal Water in Pearl millet-Mustard Crop Rotation (Hisar)
- Impact of Agra Canal Water on Ground Water Quality, Soil Properties and Crop Performance (Agra)
- Assessment of Irrigation with Treated Sewage on Soil, Crop and Ground Water Quality (Agra)
- Effect of Sea Water Intrusion on Ground water Quality in Coastal Belt of Krishna, A.P. (Bapatla)
- Survey and Minimization of Adverse Effects of Nitrate in Ground Water (Bapatla)
- Survey and Minimization of Adverse Effects of Fluoride in Ground Water (Bapatla)
- Response of Crops (Groundnut-Wheat) to Varying Levels of Salinity and Moisture under Sprinkler Irrigation (Bikaner)
- To Optimize the Zinc Requirement of Wheat Crop Irrigated with Sodic Water (Hisar)
- Studies on the Long-Term Effect of Sewage Irrigation on Soil and Crops (Trichy)
- Tolerance of Vegetable Crops to Saline Irrigation under Drip and Surface System (Agra)
- Drain Water Usage and Management Strategies of Nallamada Drain (Bapatla)
- Organic Input Management Options with Saline Water Irrigation for Enhancing Productivity of High Value Crops (Karnal)

Survey and Characterization of Ground Waters for Irrigation

Agra: Etawah district

The groundwater survey of Etawah district in Uttar Pradesh was initiated during 2008. Total four blocks viz Saifai, Jaswant Nagar, Badhpura and Basrehar blocks were surveyed upto 2009-2010. A total of 369 samples were collected and analyzed for different water constituents for their quality.

The range of parameters viz., EC, pH, SAR and RSC presented in Table 1 revealed that the EC, RSC and SAR ranged from 0.46 to 7.59 dS/m, nil to 25.7 meq/l and 0.31 to 13.9 $(mmol/l)^{1/2}$ in Saifai block, 0.54 to 2.65 dS/m, 0 to 8.8 meq/l and 0.6 to 15.3 $(mmol/l)^{1/2}$ in Jaswant Nagar, 0.8 to 6.65 dS/m, 0 to 11.0 meq/l and 0.9 to 41.7 $(mmol/l)^{1/2}$ in Badhpura and 0.6 to 5.6 dS/m, 0 to 8.8 meq/l and 1.4 to 42.2 $(mmol/l)^{1/2}$ in Basrehar block of Etawah district.

Table 1. Range of different parameters of water in four blocks of UP

Tehsils	EC_{iw} (dS/m)		pH		RSC (meq/l)		SAR $(mmol/l)^{1/2}$	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Saifai	0.46-7.59	1.15	8.9-9.5	8.9	0-25.7	2.91	0.31-13.9	3.05
Jaswant Nagar	0.54-2.65	1.0	7.7-8.5	8.3	0- 8.8	3.65	0.6- 15.3	3.22
Badhpura	0.80-6.65	2.0	8.2-9.2	8.8	0-11.0	3.5	0.9- 41.7	11.8
Basrehar	0.60-5.60	1.4	8.0-9.2	8.6	0- 8.8	2.3	1.4- 42.2	6.9

The distribution of water samples in different EC, SAR and RSC classes are presented in Table 2. The high EC_{iw} 5-10 dS/m waters were found in Safai, Badhpura and Basrehar blocks.

The high RSC waters were found in Saifai 14.5%, Jaswant Nagar 23.2%, Badhpura 20.3% and Basrehar 12.8%, respectively. Only 6.5% samples in Badhpura and 1.1% in Basrehar block have high SAR class, i.e. 30-40 and >40 $(mmol/l)^{1/2}$

Table 2. Frequency distribution of water samples in different EC, RSC and SAR classes

Particulars	Saifai (83)	Jaswant Nagar (99)	Badhpura (93)	Basrehar (94)
EC_{iw} classes (dS/m)				
0.0-1.5	94.0	96.0	52.7	74.5
1.5-3.0	3.6	4.0	30.1	23.4
3.0-5.0	-	-	12.9	1.1
5.0-10.0	2.4	-	4.3	1.1
>10.0	-	-	-	-
RSC classes (meq/l)				
Absent	4.8	1.0	30.1	14.9
0.0-2.5	54.2	33.3	34.4	41.5
2.5-5.0	26.5	42.4	15.1	30.8
5.0-10.0	13.3	23.2	20.4	12.8
>10.0	1.2	-	-	-
SAR classes $(mmol/l)^{1/2}$				
0-10	96.4	99.0	62.4	86.2
10-20	3.6	1.0	20.4	11.7
20-30	-	-	10.7	1.1
30-40	-	-	6.5	1.1
>40	-	-	-	-

Nitrate

The nitrate was observed in 10% samples of Saifai and 4% samples of Jaswant Nagar block only. Out of which 75% samples were recorded in category <2.5 meq/l and only 25% samples were recorded under category of high nitrate (>10 meq/l) in Saifai block (Table 3).

Table 3. Distribution of NO_3 in different classes and blocks (% samples)

Particulars	Saifai	Jaswant Nagar
Sample (%)	9.6	4.0
Nitrate content (%)		
0-2.5	75.0	100.0
2.5-5.0	-	-
5.0-7.5	-	-
7.5-10.0	-	-
>10	25.0	-

Fluoride

The distribution of water samples in fluoride classes showed that 67.7 to 90.4% water samples in different blocks have fluoride up to 1.5 ppm where 9.2 to 32.3% water samples contain fluoride >1.5 ppm in Safai, Jaswant Nagar, Badhpura and Basrehar blocks (Table 4).

Table 4. Distribution of fluoride in different classes and blocks (% samples)

Particulars	Saifai	Jaswant Nagar	Badhpura	Basrehar
Fluoride (ppm)				
0-1.5 (safe)	90.4	67.7	85.0	79.8
>1.5 (unsafe)	9.6	32.3	15.0	20.2

The distribution of water samples in different water quality classes (Table 5) reveals that 58% in Saifai, 35% in Jaswant Nagar, 56% in Badhpura and 54% samples in Basrehar blocks are of good quality. About 6% in Badhpura and 1% in Basrehar block are of marginal saline water quality. High SAR saline water was found in Saifai (1.2%), Badhpura (2.2%) and Basrehar (1.1%) blocks. Alkali water was reported in Badhpura (1.1%), and Basrehar (4.3%) blocks only, while major problem in rest of samples was of marginal and high alkali water, where 90, 32, 13, 26.6 per cent samples were found in marginally alkali and 22, 32, 21.5 and 12.7 per cent were of high alkali in Saifai, Jaswant Nagar, Badhpura and Basrehar blocks, respectively.

Table 5. Distribution of water samples in different water quality ratings

Quality of waters	EC_{iw}	SAR	RSC	Saifai (83)	Jaswant Nagar (99)	Badhpura (93)	Basrehar (94)
Good	<2	<10	<2.5	57.8	35.3	55.9	54.3
Marginally saline	2-4	<10	<2.5	-	-	6.4	1.1
Saline	>4	<10	<2.5	-	-	-	-
High SAR saline	>4	>10	<2.5	1.2	-	2.2	1.1
Marginally alkali	<4	<10	2.5-4	19.3	32.3	12.9	26.6
Alkali	>4	<10	>4	-	-	1.1	4.3
High alkali	<4>	>10	>4	21.7	32.3	21.5	12.8

Bikaner: Sikar district

The water quality survey of Sikar district was initiated in 2008-09. Survey of Fetehpur tehsil was completed during 2009-10. Water samples from 148 tube wells of 119 villages were collected. The water table varied from 30.0 m to 66.7 m. EC and pH of water samples ranged from 1.2 to 6.2 dS/m and 8.0 to 9.1 respectively. The concentration of calcium and magnesium varied from 0.4 to 5.0 and from 0.5 to 13.8 meq/l whereas concentration of potassium ion varied from 0.03 to 0.33 meq/l. Soluble carbonates and bicarbonates varied from 3.8 to 32.0 meq/l, though the carbonates were only in few villages. The concentration of chloride and sulphate were in range of 2.2 to 46.2 and 0.2 to 9.1 meq/l respectively. Sodium was dominant cation while chloride was dominant anion. Nitrate content ranged in between 80 to 130 mg/l. SAR and soluble sodium percentage (SSP) of water samples ranged 6.8 to 48.1 and 67.0 to 97.0, respectively (Table 6).

The distribution of water samples in different range of EC and RSC are presented in Table 7. As regard to salinity, 11.5, 66.5 and 22 per cent water samples showed EC in the range of <2.0, 2.0-4.0 and >4.0 dS/m, respectively. RSC of water ranged from nil to 26.4. About 6 and 92 per cent water samples have RSC in the range of 5.0 to 7.5 and >7.5 meq/l.

Table 6. Chemical characteristics of tube well water and soils of Fatehpur tehsil of Sikar district

Characteristics	Water	Soil
pH	8.0-9.1 (8.3)*	8.4- 10.5 (9.7)*
EC (dS/m)	1.2-6.2 (3.3)*	0.14- 0.63
Ca (meq/l)	0.4-5.0	0.2- 1.1
Mg (meq/l)	0.5-13.8	0.3 -1.3
Na (meq/l)	10.2-51.0	0.3- 4.30
K (meq/l)	0.03-0.33	0.03 – 0.33
CO_3+ HCO_3 (meq/l)	3.8-32.0	1.0 -3.9
Cl (meq/l)	2.2-46.2	0.2- 2.4
SO_4 (meq/l)	0.2-9.1	0.02-0.88
RSC (meq/l)	Nil -26.4	-
SAR $(mmol/l)^{1/2}$	6.8-48.1	0.4-5.8
SSP	67.0-97.0	
Mg/Ca ratio	1.0 -4.8	
Water table (m)	30.0-66.7	
Floride (mg/l)	0.55-2.15	
NO_3 (mg/l)	80-130	

** Figures in parenthesis of column 2 are the average value*

Table 7. Distribution (per cent) of water samples in different ranges of EC and RSC

RSC (meq/l)	EC_{iw} (dS/m)					
	< 1	1-2	2-3	3-4	>4	Total
<2.5	-	1.0	-	-	-	1.0
2.5-5.0	-	-	-	-	1.0	1.0
5.0 – 7.5	-	1.5	2.0	1.5	1.0	6.0
>7.5	-	9.0	43.0	20.0	20.0	92.0
Total	-	11.5	45.0	21.5	22.0	

Per cent distribution of water samples in relation to SAR, SSP, F and Mg/Ca ratio showed about 81.3 and 10.4 per cent water samples have SAR 10-20 and 20-30, respectively and 58.3 per cent water samples showed SSP in the range of 70-80 while 41.7 per cent water samples have SSP more than 80.

Mg/Ca ratio was always more than 1 while 25% of the water samples have F in the range of 1-5 mg/l. (Table 8).

Table 8. Distribution (%) of water samples in relation to SAR, SSP, Mg/Ca ratio and fluoride

Characteristics	Percentage	Characteristics	Percentage
SAR		SSP	
0-10	8.3	< 50	0.0
10-20	81.3	50-60	0.0
20-30	10.4	60-70	0.0
>30	0.0	70-80	58.3
Mg /Ca ratio		>80	41.7
<1	0.0	F (mg/l)	
1-2	16.7	<1.5	75.0
2-3	43.8	1.5 - 5.0	25.0
>3	39.5	5.0 - 10.0	0.0
		>10.0	0.0

Percentage distribution of different categories of water quality of Fetehpur tehsil is presented in Fig. 1. It is seen that more than 90% of the ground water in the tehsil are highly alkali in nature. As such, the farmers need to adopt chemical amendment technology to make best use of these waters.

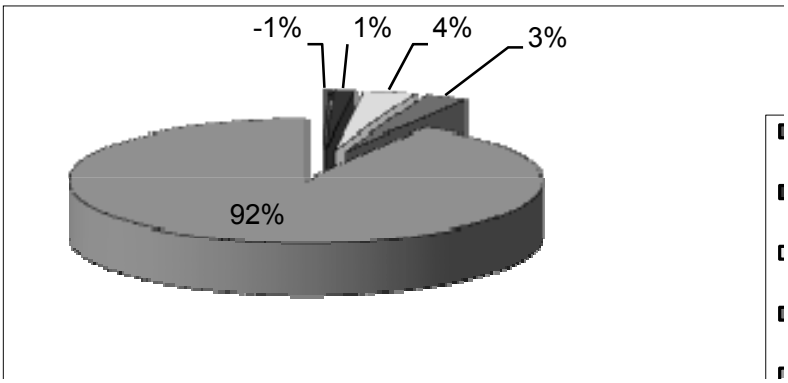


Fig. 1. Distribution of different categories of water quality in Fetehpur tehsil of Sikar district

Gangawati: Gulbarga district

The ground water quality characterization of Gulbarga district, Karnataka was initiated during 2004-05 and continued during 2006-07, 07-08 and 08-09. During 2008-09, two more taluks of the district viz., Afjalpur and Aland were surveyed and a total of 154 and 220 ground water samples were collected from these taluks. Thus, survey and characterization of underground irrigation water of entire Gulbarga district was completed.

Majority of water samples in Afjalpur (94.8%) and Aland (86.4%) had pH ≤ 8.5. Similarly, 90.9% and 96.3% of samples in Afjalpur and Aland were found to be non-saline at the time of sampling respectively as revealed by the electrical conductivity. Among cation and anion, Na and Cl ions were dominant in both the taluks. Overall water quality ratings indicated that 83.8% and 87.3% water samples were of good quality in Afjalpur and Aland taluk respectively. The extent of occurrence of saline water with or without high SAR was 12.3% and 5.0% in Afjalpur and Aland respectively. Among the problematic waters, marginal alkali (RSC 2.5-4.0 meq/l) was predominant in Aland (7.7%) followed by Afjalpur (3.9%).

With regards to the overall water quality, Gulbarga district as a whole registered 77.6% of good quality water. As shown in Table 9, frequency of occurrence of good quality water in the talukas surveyed followed the order: Jewargi (94.6%) >Gulbarga (90.8%) >Aland (87.3%) >Afjalpur (83.8%) >Chincholli (77.0%) >Surpur (74.0%) >Shahpur (72.7%) >Sedam (60.8%) >Chittapur (57.5%). Among taluks, Jewargi (94.6%) and Chittapur (57.7%) registered the maximum and minimum frequency of occurrence of good quality water, respectively. Except Afjalpur and Surpur taluks, the extent of occurrence of saline water with or without high SAR was considerably less (<4.0%). Among the problematic waters, marginal alkali (RSC 2.5-4.0 meq/l) was highest and lowest in Chittapur (28.1%) and Jewargi (1.2%) respectively with an overall district average of 12.12%. The Sedam taluk registered the highest percentage (15.4%) of highly alkali water compared to other taluks.

Table 9. Water quality ratings (%) of ground waters of different taluka of Gulbarga district

Taluk/ District	Sample size	Good	Marginal saline	Saline	High SAR saline	Marginal alkali –I	Marginal alkali –II	Alkali
Jewargi	167	94.6	0.6	0.6	3.0	1.2	0	0
		(158)*	(1)	(1)	(5)	(2)		
Gulbarga	195	90.8	3.6	0	0.5	4.6	0	0.5
		(177)	(7)		(1)	(9)		(1)
Surpur	266	74.0	2.6	0.8	6.4	10.1	2.3	3.8
		(197)	(7)	(2)	(17)	(27)	(6)	(10)
Shahapur	253	72.7	0.8	1.2	3.9	17.0	0.8	3.6
		(184)	(2)	(3)	(10)	(43)	(2)	(9)
Chittapur	188	57.5	5.9	-	2.1	28.1	0.5	5.90
		(108)	(11)		(4)	(53)	(1)	(11)
Sedam	130	60.8	-	-	1.5	19.2	3.1	15.4
		(79)			(2)	(25)	(4)	(20)
Chincholi	156	77.0	0.6	-	-	17.3	1.9	3.20
		(120)	(1)			(27)	(3)	(5)
Afjalpur	154	83.8	4.5	-	7.8	3.9	-	-
		(129)	(7)		(12)	(6)		
Aland	220	87.30	3.60	-	1.4	7.7	-	-
		(192)	(8)		(3)	(17)		
Gulbarga	1729	77.61	2.46	0.28	2.97	12.12	0.96	3.6
district		1344)	(44)	(6)	(54)	(209)	(16)	(56)

**Figures in the parentheses indicate number of samples.*

During 2009-10, survey and collection of ground water samples village-wise from Gadag and Mundaragi taluks of Gadag district was carried out. Gadag is predominantly an agriculture based district with an average annual rainfall of 612.5 mm. This district has 5 taluks with net sown area of nearly 76% of the total geographical area. About 17% of the net sown area has irrigation facility. Of which irrigation through borewell and wells comprise about 40% of the total irrigated area.

A total of 254 samples (Gadag-156 and Mundaragi–98 samples) representing almost all the villages from these taluks were collected and analyzed. Majority of water samples in both the taluks had favorable pH i.e. ≤ 8.0 without any potential alkali hazard upon use for irrigation. At the time of sampling as revealed by the electrical conductivity, 60.25 and 75.5% of water samples in Gadag and Mundarigi taluks respectively were found to be non-saline (EC<2 dS/m). However, considerable percentage of samples i.e., 28.8 and 20.4% in Gadag and Mundarigi taluks respectively were found to be marginally saline (EC 2-4 dS/m). Nearly 11% of water samples in Gadag taluk were saline reflecting the possibility of salinity hazard upon use of such water for irrigation.

In the samples analyzed, Na ion was dominant followed by Mg, Ca and K. At all the levels of EC, the mean Mg/Ca ratios in both the taluks were higher than 0.63 which was reported to be critical for causing Mg hazard. Among anion, Cl ion was dominant in both the taluks followed by HCO_3 , SO_4 and CO_3. The mean chloride contents were higher than 3.0 me/l in both the taluks. Cl/SO_4 ratio was also >2.0 in majority of samples except in Mundarigi taluk at EC >4.0 dS/m.

As shown in Table 10 with regards to the water quality ratings, less than 50% of samples in both the taluks were of good quality. In Gadag and Mundaragi taluks 47.4 and 39.8% of water samples were found to be of problematic nature which requires special attention and suitable recommendation for their use in agriculture.

Table 10. Water quality ratings of ground waters of different taluks of Gadag district

Taluk	Sample size	Good	Marginal saline	Saline	High saline	Marginal alkali –I	Marginal alkali- II	Alkali
Gadag	156	31.41 (49)*	21.15 (33)	8.33 (13)	5.13 (8)	12.18 (19)	8.33 (13)	13.46 (21)
Mundaragi	98	45.92 (45)	14.29 (14)	1.02 (1)	4.08 (4)	8.16 (8)	12.24 (12)	14.29 (14)

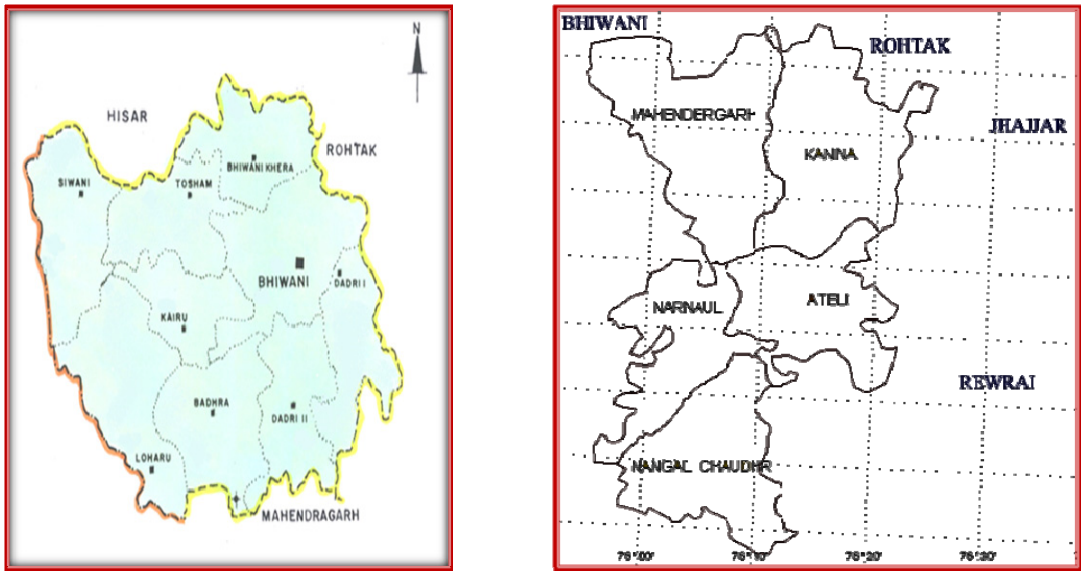
**Figures in the parenthesis represent number of samples*

Hisar: Bhiwani and Mahendragarh districts

During 2008-09, survey and characterization of ground irrigation water of Loharu, Kairu, Dadri, Tosham, and Siwani blocks of Bhiwani district (Haryana) and during 2009-10, Mahendragarh, Kanina, Ateli, Narnaul and Nangal Chaudhary blocks of Mahendragarh district were undertaken (Fig. 2a). The elevation, longitude and latitude angles of the sampling points were recorded by GPS system at each location.

Bhiwani

The range and mean of different water quality parameters of 678 ground water samples collected from different blocks (82 from Loharu, 74 from Kairu, 144 from Dadri, 173 from Tosham, 205 from Siwani) of Bhiwani district are presented in Table 10a, b. The average chemical composition and related quality parameters in different EC ranges for Loharu block are given in Table 11. It showed that per cent samples in EC classes increased with increase in the EC of groundwater up to 4 dS/m and afterwards, percentage of samples started decreasing gradually with further increase in EC of irrigation water. The maximum number of 32 samples was concentrated in 3-4 dS/m EC class. It is seen that 76.87 per cent samples were found in lower range of EC (up to 4 dS/m), whereas there was no sample found in the lowest EC class (0-1 dS/m). Similar analysis for other blocks was carried out but not included for brevity. Ground water quality distribution in Loharu block of Bhiwani district is depicted in Fig. 2b.



Bhiwani **Mahendragarh**

Fig. 2a. Location maps of the study area

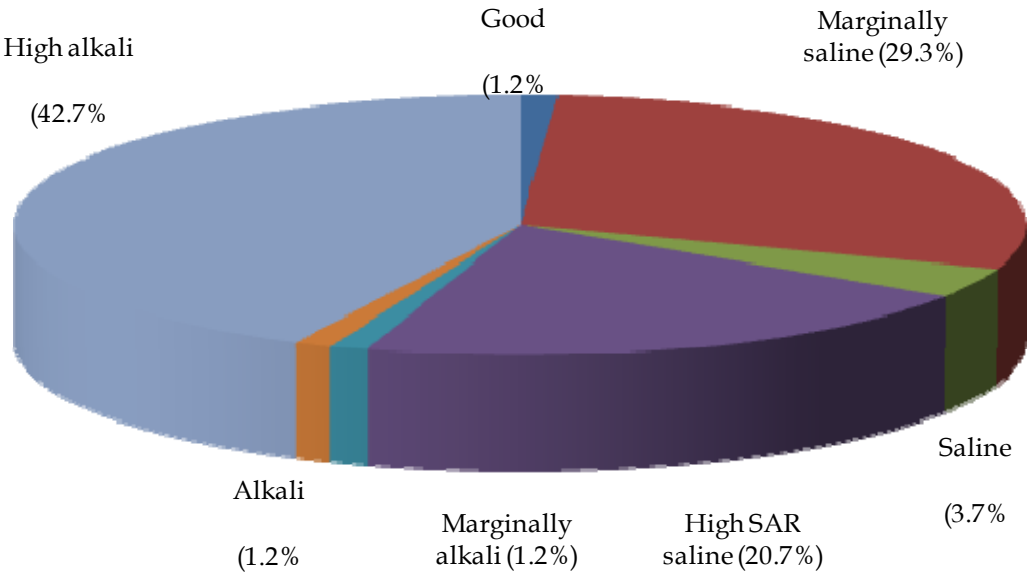


Fig. 2b. Ground water quality distribution in Loharu block of Bhiwani district

Table 10a. Water quality parameters of Loharu, Kairu and Dadri blocks of Bhiwani district

Parameters	Loharu		Kairu		Dadri	
	Range	Mean	Range	Mean	Range	Mean
EC (dS/m)	1.27-9.20	3.35	0.45-18.2	5.69	0.3-15.22	4.29
pH	7.70-8.90	8.33	7.46-9.38	8.40	7.46-9.71	8.48
Na (meq/l)	6.94-77.76	27.08	3.08-108.01	46.46	0.98-101.4	31.44
Ca (meq/l)	1.00-12.20	4.29	0.90-47.0	6.92	0.4-44.40	4.87
Mg (meq/l)	0.50-27.90	7.66	1.10-70.2	15.86	0.4-50.20	10.13
K (meq/l)	0.06-0.21	0.12	0.023-1.54	0.151	0.03-1.08	0.17
Cl (meq/l)	4.80-60.0	17.24	3.20–134.0	38.63	1.8-122.2	29.68
CO_3 (meq/l)	0.00-3.60	0.47	0.00-5.60	1.30	0.0-4.00	0.50
HCO (meq/l)	7.20-20.0	12.65	5.40–24.0	12.58	1.2-34.80	7.28
SAR (mmol/l)½	3.37-20.91	11.79	1.45-33.65	14.58	0.85-38.74	11.62
RSC (meq/l)	Nil-14.80	4.19	0.00-25.4	2.91	0.0-12.60	1.13
SO_4 (meq/l)	--	--	--	--	--	--
F^- (mg/l)	--	--	--	--	--	--
NO_3 (mg/l)	--	--	--	--	--	--

Table 10b. Water quality parameters of Tosham and Siwani blocks of Bhiwani district

Parameters	Tosham		Siwani	
	Range	Mean	Range	Mean
EC (dS/m)	0.48-17.53	5.93	0.28-13.96	4.92
pH	7.50-9.10	8.35	7.80-9.10	8.50
Na (meq/l)	0.50-125.10	28.84	0.0-121.72	31.12
Ca (meq/l)	0.80-55.14	9.62	0.52-40.37	10.06
Mg (meq/l)	0.35-71.78	12.1	0.80-47.10	10.94
K (meq/l)	0.0-1.19	0.24	0.0-2.30	0.39
Cl (meq/l)	1.21-141.10	32.05	0.60-140	31.71
CO_3 (meq/l)	0.0-3.20	0.69	0.0-4.70	0.90
HCO_3 (meq/l)	0.0-10.90	3.03	0.40-16.05	3.69
SAR (mmol/l)½	0.32-45.74	8.64	0.0-28.45	9.52
RSC (meq/l)	0.0-5.56	0.36	0.0-11.43	0.53
SO_4 (meq/l)	0.20-62.24	15.45	0.50-78.23	16.40
F (mg/l)	0.0-2.13	0.47	0.0-2.97	0.57
NO_3 (mg/l)	0.0-3.25	0.63	0.0-3.60	0.45

According to AICRP criteria, per cent categorization of 678 water samples collected from the five blocks of Bhiwani district is shown in Table 12. Among these blocks, good quality water was found maximum in Dadri block, marginally saline in Loharu block, saline in Siwani block, high SAR saline in Kairu block, marginally alkali in Dadri block, alkali in Kairu and highly alkali in Loharu block.

Mahendragarh

The range and mean of different water quality parameters of 299 underground water samples collected from different blocks (87 from Mahendragarh, 54 from Kanina, 59 from Ateli, 42 from Narnaul and 57 from Nangal Chaudhary) of Mahendragarh district are presented in Table 13a, b.

Table 11. Chemical composition of ground water samples of Loharu block in different EC classes

EC classes (dS/m)	No. of sam--ples	% of sam--ples	Na	Ca	Mg	K	CO_3	HCO_3	Cl	RSC	SAR $(mmol/l)^{½}$
			(meq/l)								
0-1	-	-	-	-	-	-	-	-	-	-	-
1-2	15	18.29	16.27	1.73	3.10	0.10	0.48	13.8	7.98	9.44	11.25
2-3	16	19.54	21.80	3.72	5.59	0.10	0.45	12.37	13.65	5.34	11.02
3-4	32	39.04	26.24	4.22	7.53	0.11	0.54	13.19	16.63	3.45	11.49
4-5	13	15.85	33.15	5.93	10.1	0.14	0.32	11.16	22.38	0.49	12.20
5-6	2	2.43	40.27	7.7	21.1	0.15	0.5	10.6	34	Nil	10.93
6-7	2	2.43	64.32	8.5	13.4	0.15	0.3	11.08	42.4	Nil	19.44
7-8	1	1.21	70.35	10.0	23	0.18	0.6	11.08	40	Nil	17.32
8-9	-	-	-	-	-	-	-	-	-	-	-
9-10	1	1.21	77.77	12.2	27.8	0.19	0.6	11	60	Nil	17.39

Table 12. Ground water quality classification (per cent) of five blocks of Bhiwani district

Water quality	Loharu	Kairu	Dadri	Siwani	Tosham
Good	1.2	6.8	24.3	17.1	26.6
Saline waters					
Marginally saline	29.3	1.4	18.1	21.4	23.1
Saline	3.7	--	6.3	20.5	13.3
High SAR saline	20.7	60.8	36.1	31.2	31.2
Alkali waters					
Marginally alkali	1.2	--	3.5	1.0	2.3
Alkali	1.2	8.1	5.6	0.5	1.2
Highly alkali	42.7	22.9	6.3	8.3	2.3
Total samples	82	74	144	205	173

Table 13a. Quality parameters of water samples of blocks of Mahendragarh district

Parameters	Mahendragarh		Kanina		Ateli	
	Range	Mean	Range	Mean	Range	Mean
EC (dS/m)	0.5 – 9.65	2.16	0.35 – 9.29	2.37	0.84 – 5.3	2.09
pH	7.00 – 10.12	8.30	7.53 – 9.37	8.51	7.39 – 8.98	8.23
Na (meq/l)	1.01 – 58.2	15.04	3.4 – 63.63	20.04	5.69 – 34.12	16.57
Ca (meq/l)	0.3 – 19.5	2.77	0.5 – 12.2	2.4	0.2 – 11.1	2.47
Mg (meq/l)	0.19 – 26.3	4.59	1.4 – 81.4	14.79	0.3 – 8.8	3.72
Cl (meq/l)	1.3 – 88.0	14.35	2.1 – 93.6	17.18	3.5 – 47.0	13.05
CO_3 (meq/l)	Nil – 4.8	0.63	0.0 – 4.0	1.08	0.0 – 3.0	0.79
HCO_3 (meq/l)	0.6 – 16.96	5.36	2.0 – 11.2	5.98	3.6 – 11.2	6.52
SAR $(mmol/l)^{½}$	0.54 – 17.32	8.77	3.98 – 25.04	12.36	3.18 – 26.02	10.44
RSC (meq/l)	Nil – 14.72	2.14	0.0 – 13.0	3.10	0.0 – 8.00	2.68

In Mahendragarh block, ground water samples were collected from the entire block except in some parts of the Western side of the block, water samples could not be collected due to existence of small hill. In the block, electrical conductivity (EC) ranged from 0.5 to 9.65 dS/m with a mean of 2.16 dS/m (Table 13).

The average chemical composition and related quality parameters in different EC range for Mahendragarh block are given in Table 14. The per cent samples in EC classes 0 - 1 and 1 – 2 dS/m is

same and afterwards, percentage of samples started decreasing gradually with further increase in EC of irrigation water. It is seen that 57.48 per cent samples were found upto EC of 2 dS/m, whereas, there was no sample found in the EC class of 7-8 dS/m.

Table 13b. Quality parameters of water in blocks of Mahendragarh district

Parameters	Narnaul		Nangal Choudhary	
	Range	Mean	Range	Mean
EC (dS/m)	0.44 – 8.15	2.85	0.71-5.25	1.87
pH	7.2 – 9.14	8.29	7.45-9.37	8.52
Na (meq/l)	3.95 – 53.17	21.36	5.90-36.23	15.74
Ca (meq/l)	0.6 – 10.9	3.22	0.5-10.0	2.14
Mg (meq/l)	0.9 – 16.1	4.85	1.06-10.3	3.05
Cl (meq/l)	0.0 – 4.8	0.67	3.80-38.0	11.99
CO_3 (meq/l)	1.8 – 14.0	6.64	nil-3.60	0.93
HCO_3 (meq/l)	2.6 – 74.0	21.33	3.0-12.0	6.38
SAR $(mmol/l)^{½}$	0.0 – 13.6	2.36	4.48-19.10	10.64
RSC (meq/l)	3.28 – 18.03	10.98	Nil-12.0	3.32

Table 14. Chemical composition of ground water of Mahendragarh block in different EC classes

EC classes (dS/m)	No. of sam--ples	% of sam--ples	Na	Ca	Mg	CO_3	HCO_3	Cl	RSC	SAR $(mmol/l)^{½}$
			(meq/l)							
0-1	25	28.74	6.40	0.86	1.40	0.34	3.34	3.54	1.79	7.04
1-2	25	28.74	11.11	1.42	2.30	0.82	6.98	6.19	4.25	8.71
2-3	16	18.39	17.35	3.13	6.04	0.86	5.94	14.87	1.63	9.14
3-4	8	9.20	24.32	3.77	6.28	1.00	5.93	24.90	1.11	11.34
4-5	8	9.20	27.22	6.36	8.84	0.30	5.45	34.95	0.00	10.33
5-6	3	3.45	27.36	9.00	16.10	0.00	5.20	48.83	0.00	8.42
6-7	1	1.15	40.84	6.80	14.20	0.80	4.80	54.00	0.00	12.60
7-8	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8-9	1	1.15	58.20	19.50	26.30	0.40	2.40	88.00	0.00	12.16

Overall in Mahendragarh district, 93, 62, 38, 37, 36, 18 and 15 samples were found in highly alkali, good, marginally alkali, marginally saline, high SAR saline, saline and alkali, respectively (Table 15). Most of the groundwater in the district was under the category of high alkali (31.2%).

Table 15. No. of samples categorized in water quality classes for blocks of Mahendragarh district

Water quality	Mahendragarh	Kanina	Ateli	Narnual	Nangal Choudhary	Total	Per cent sample
Good	22	9	10	8	13	62	20.7
Saline waters							
Marginally saline	11	3	13	6	5	38	12.7
Saline	9	1	4	1	3	18	6.0
High SAR saline	11	11	1	11	2	36	12.0
Alkali waters							
Marginally alkali	17	4	6	3	7	37	12.4
Alkali	5	2	0	6	2	15	5.0
Highly alkali	12	24	25	7	25	93	31.2
Total samples	87	54	59	42	57	299	100.0

Since RSC problem is quite prevalent in Mahendragarh district, contour map of RSC was developed to identify hot spots. The highest RSC (14.72 meq/l) in water samples was observed in village Bhurjat of Mahendragarh block. It was observed from the contour map (Fig. 3) that the RSC of groundwater is high in the middle and upper (Northern) part of the district where red colour contour are shown. In the map, with the increase in the intensity of red colour, RSC in groundwater increases. In most parts of the district, RSC is less than or equal to 11 meq/l.

Indore: Mandsaur district

The survey and characterisation of ground water of Mandsaur, Malhargarh, Sitamau, Suwasara, Garoth and Bhanpura tehsils of Mandsaur district of Madhya Pradesh was undertaken during 2009-10. The district has semi-arid to arid subtropical monsoon type climate and receives an annual rainfall of about 600-700 mm. Maximum and minimum temperatures are 45°C and 8°C respectively. The soils of the area are generally classified in the order of Vertisols and Inceptisols and most of the soils have originated from basaltic rocks. Moderately deep to deep soils also prevailed in the region. The district is situated in the western part of the state and lies between 23º45´30.60˝N - 24º46´01.58˝N and 75º46´02.55˝E - 75º56´32.43˝E. A variety of crops like wheat, garlic, poppy, mustard, citrus, papaya, chillies, coriander and berseem are the main crops grown in the district. Open wells and tube wells are used to irrigate these crops.

Three hundred fifty four ground water samples were collected which includes samples from open wells and tube wells. The wells/tube wells vary in depth from 5 to 400 m depth. The quality of ground water samples collected from the district indicated that pH, EC, SAR and RSC range from 7.1 to 8.4, 0.28 to 6.10 dS/m, 0.6 to 16.0 $(mmol/l)^{1/2}$ and 0.0 to 11.1 meq/l, respectively (Table 16). Out of 354 samples 314 (88.7%) samples were classified as good quality (A) waters, whereas, 38 (10.7%) samples saline (B) and 02 (0.6%) samples comes under alkali (C) waters (Table 17). The saline waters were further categorized as marginally saline (B_1- 10.1%), saline (B_2 – 0.3%), and high SAR saline (B_3 – 0.3%) category. The alkali waters were again sub divided into marginally alkali (C_1- 0.3 %), alkali (C_2 – 0.0%) and highly alkali (C_3 – 0.3%) categories. Garoth tehsil was most badly affected by poor quality waters (19.8%) followed by Bhanpura (10.9%), Mandsaur (9.4%) and Malhargarh (9.1%) (Table 17). The waters were of Ca-Mg-Na type with the dominance of bicarbonates followed by chlorides. The map showing area of saline and alkali waters was generated using GIS technique (Fig. 4)

Table 16. Salient features of ground water samples of Mandsaur district

Parameters	Mandsaur	Malhargarh	Sitamau	Suwasara	Garoth	Bhanpura
pH	7.1-7.9	7.2-7.9	7.1-7.9	7.2-7.8	7.1-8.4	7.1-8.3
EC (dS/m)	0.45-3.28	0.36-2.84	0.49-3.78	0.57-4.81	0.47-6.10	0.28-2.88
SAR $(mmol/l)^{1/2}$	0.8-8.2	0.6-5.7	0.7-8.0	0.7-4.9	0.6-16.0	0.7-10.1
RSC (meq/l)	0.0-0.8	0.0-1.2	0.0-1.4	0.0-0.2	0.0-2.8	0.0-11.1

Table 17. Frequency distribution of samples into various categories in Mandsaur district

Category	Tehsils of Mandsaur district						Total
	Mandsaur	Malhargarh	Sitamau	Suwasra	Garoth	Bhanpura	
A	87	30	45	38	73	41	314
B_1	9	3	4	-	16	4	36
B_2	-	-	-	1	-	-	01
B_3	-	-	-	-	1	-	01
C_1	-	-	-	-	1	-	01
C_2	-	-	-	-	-	-	00
C_3	-	-	-	-	-	1	01
Total	96	33	49	39	91	46	354

A: Good quality; B_1 : Marginally saline; B_2 : Saline; B_3 : High SAR saline;
C_1 : Marginally alkali; C_2 : Alkali; C_3 : Highly alkali

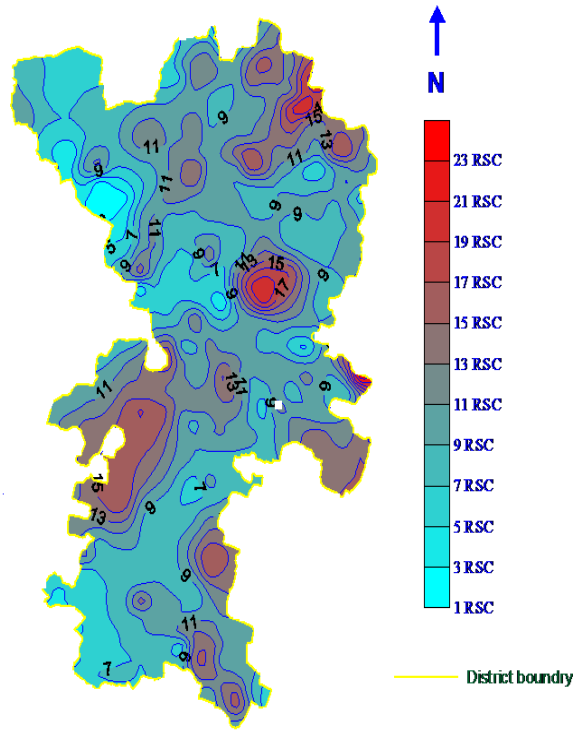


Fig. 3. Contour map of RSC of ground water in Mahendragarh district

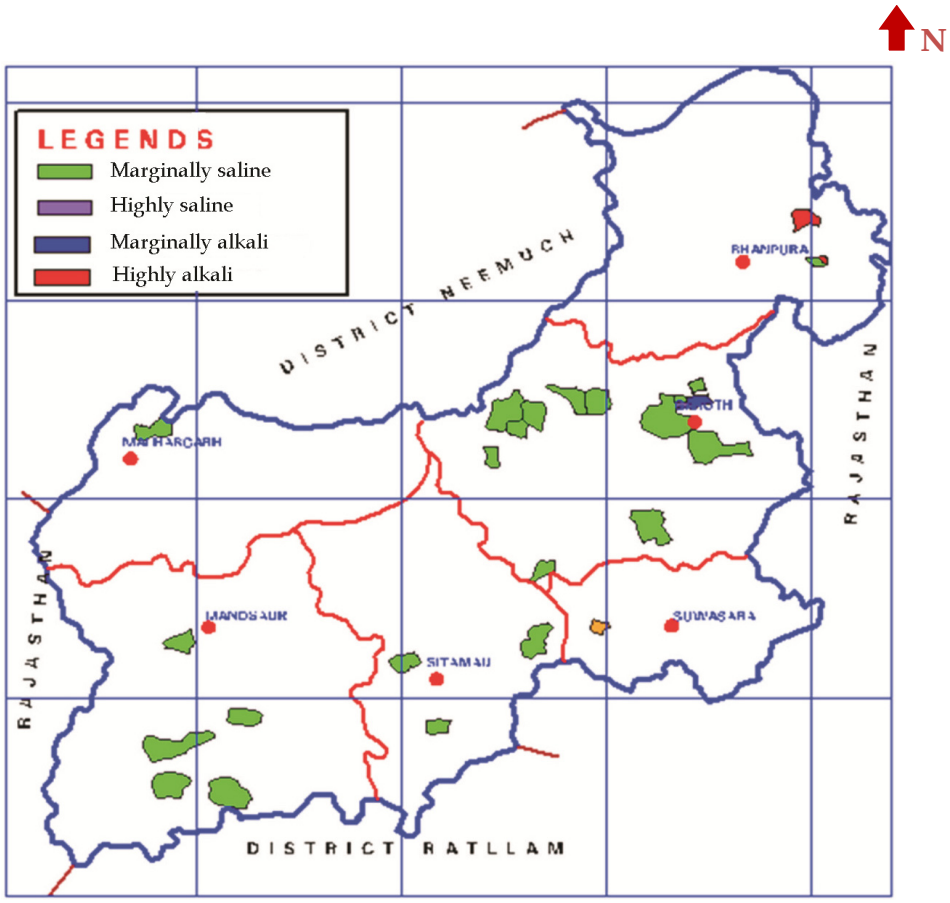


Fig 4. Ground water quality map of Mandsaur distict

Kanpur: Rae Bareli district

The survey and characterization of underground irrigation water of Lalganj tahsil of Raebareli district of Uttar Pradesh was carried out. The district is surrounded by Barabanki, Sultanpur, Pratapgarh, Unnao and Lucknow districts. The district is situated between 26^0 34′ N to 25^0 53′ N latitude and between 81^0 06′ E to 81^0 20′ E longitude. Ground water samples were collected from Khiron (49), Sareni (82) and Lalganj (46) blocks of Raebareli district.

In Khiron block, the quality of groundwater samples indicated that pH, EC, SAR and RSC ranged from 7.1 to 8.2, 0.45 to 3.61 dS/m, 1.2 to 9.6 and 0.0 to 5.1 meq/l respectively (Table 18). Most of the water samples belonged to good category. Out of 49 samples, only three samples come in the category of marginally saline and one in alkali category (Table 19). Among anion, chloride and among cations calcium was the dominant ion.

In Sarani block, the quality of ground water samples indicated that pH, EC, SAR and RSC ranged from 7.2 to 8.2, 0.46 to 3.27 dS/m, 0.7 to 8.6 and 0.0 to 6.8 meq/l respectively (Table 18). Most of the water belonged to category good (72 samples). Out of 82 samples, only ten samples fall in the category of marginally saline water (Table 19). The water samples were Na rich with the dominance of chloride followed by bicarbonate.

In Lalganj block, the quality of ground water samples indicated that pH, EC, SAR and RSC ranged from 7.2 to 8.1, 0.47 to 4.06 dS/m, 0.9 to 9.8 and 0.0 to 2.7 meq/l respectively (Table 18). Out of 46 groundwater samples, 37 samples fall in good category. The Ca, Na, HCO_3 and Cl were dominant ions in the groundwater samples of Lalganj block. Seven samples belonged to marginally saline water category, one sample each belongs to saline and marginally alkali category (Table 19).

Table 18. Salient features of ground water samples of Lalganj tehsil of Raibareli district

Block	pH	EC (dS/m)	SAR	RSC (meq/l)
Khiron	7.1-8.2	0.45-3.61	1.2-9.6	0.0-5.1
Sareni	7.2-8.2	0.46-3.27	0.7-8.6	0.0-6.7
Lalganj	7.2-8.1	0.47-4.06	0.9-9.8	0.0-2.7

Table 19. Frequency distribution of ground water into different categories of water quality in Raebareli district

Category	Khiron	Sareni	Lalganj	Total
Good	45	72	37	154
Marginally saline	3	10	7	20
Saline	-	-	1	1
High saline	-	-	-	-
Marginally alkali	-	-	1	1
Alkali	1	-	-	1
Highly alkali	-	-	-	-
Total samples	49	82	46	177

Tiruchirapalli: Permabalur and Ariyalur districts

The groundwater quality of Permabalur district (680 samples) and Ariyalur district (835 samples) of Tamil Nadu were characterized by collecting water samples from both open wells and bore wells. In

general, the distribution of cations followed the order of Ca, Mg >Na >K. However in high RSC water samples, the distribution of cations followed the order of Na >Ca, Mg >K. Similarly the distribution of anions followed the order of HCO_3 >Cl >SO_4 when the irrigation water quality is good (EC <2 dS/m). But the distribution of anions followed the order of Cl >HCO_3 >SO_4 in the EC range of 2 to 4 dS/m and Cl >SO_4 >HCO_3 in the EC range >4 dS/m.

Among the four blocks of Perambalur district, the distribution of good quality samples were the highest in Perambalur Block (69.2%) and the lowest in Alathur (37.1%) block (Table 20). The occurrence of marginally saline water (13.3 to 42.8%) was prevalent in all the blocks. The saline waters were prevalent in Alathur (8.5%) and Veppur (2.5%) blocks, while the occurrence of alkali waters was reported in Veppanthattai (15%) and Alathur (2.5%) blocks. The marginally saline (13.3 to 42.8%) and marginally alkali (2.5 to 25%) waters are prevalent in almost all the blocks. High SAR saline water was reported in Alathur Block only (2.8%). The range of mean value of pH, EC_{iw}, RSC and SAR blockwise are given in Table 21. The water quality distribution as per AICRP classification is shown in Fig. 5 and water quality map of district in Fig. 6.

Table 20. Ground water quality distribution (%) in Perambalur district

Block	No. of samples	Distribution (%)						
		Good	MS	Saline	HSS	MA	Alkali	HA
Perambalur	132	69.2	18.2	-	-	12.6	-	--
Veppanthattai	147	46.6	13.3	-	-	25.0	15	-
Veppur	210	64.1	30.7	2.5	-	2.5	-	--
Alathur	191	37.1	42.8	8.5	2.8	5.7	2.8	--

MS : Marginally saline; HSS : High SAR saline; MA : Marginally alkali; HA :Highly alkali

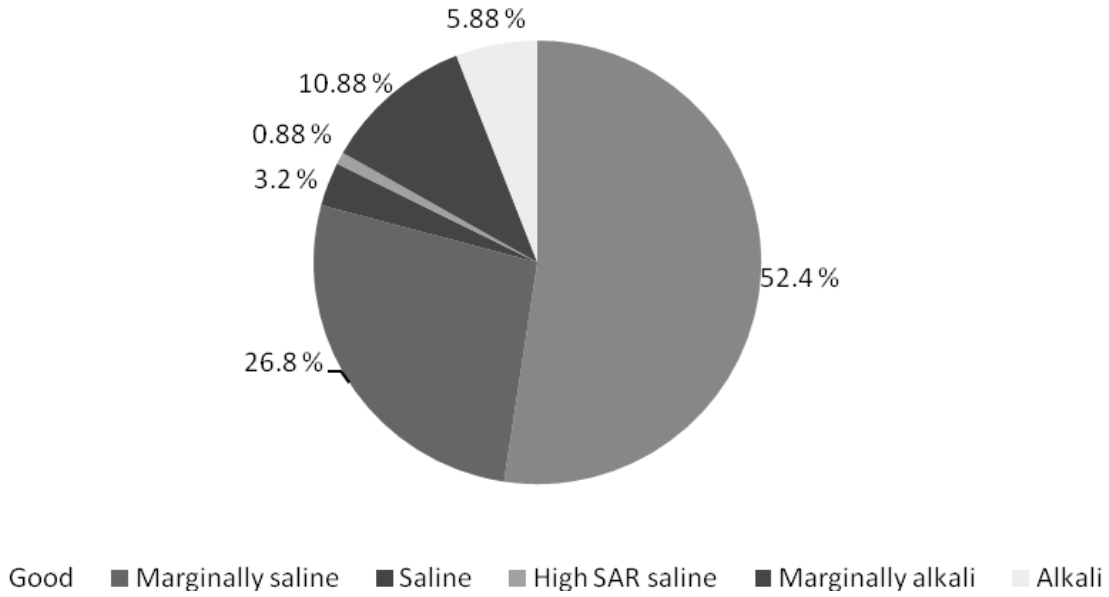


Fig. 5. Percentage distribution of ground water quality in Perambalur district

Table 21. Ground water quality in different blocks of Perambalur district

Blocks	pH			EC (dS/m)			RSC (meq/ l)			SAR		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Perambalur	7.59	8.73	8.13	0.52	3.04	1.27	Nil	3.1	0.65	0.45	7.1	2.36
Veppanthattai	7.25	9.03	8.27	0.15	3.55	1.17	Nil	7.4	0.72	0.42	7.2	4.21
Veppur	7.12	8.78	7.91	0.11	7.22	1.71	Nil	3.0	0.48	0.14	5.33	1.98
Alathur	6.8	9.93	8.03	0.57	6.13	2.27	Nil	4.6	0.69	0.7	10.2	3.2

Ariyalur district has six blocks namely Ariyalur, Thirumanur, Andimadam, Jayankondam, T.Palur and Senthurai. Among the six blocks, the distribution of good quality samples were the highest in Andimadam block (73.4 %) and the lowest in Jayankondam (56.5%) block (Table 22). The occurrence of marginally alkali water (8.72 to 30.4 %) was prevalent in all the Blocks. Marginally saline water was prevalent in Ariyalur (8.72%), Thirumanur (15.4%), Jayankondam (8.7%) and Senthurai (4.17%) blocks. The saline waters were prevalent in Ariyalur (3.49%), Thirumanur (3.36%) and Senthurai (5%) blocks, while the occurrence of alkali waters are reported in Ariyalur (2.91%), Thirumanur (3.36%), Jayankondam (4.35), T.Palur (3.65%) and Senthurai (8.33%) blocks. Highly alkali water is reported only in Ariyalur block (2.33%). The range and mean values of EC, pH, RSC and SAR blockwise are given in Table 23. The water quality map of the district is depicted in Fig. 7.

Table 22. Ground water quality distribution (%) in different blocks of Ariyalur district

Blocks	No.of samples	Good	MS	Saline	HSS	MA	Alkali	HA
Ariyalur	172	68.0	8.72	3.49	-	14.53	2.91	2.33
Thirumanur	149	69.13	15.4	3.36	-	8.72	3.36	-
Andimadam	142	73.4	-	-	-	24.6	-	-
Jayankondam	115	56.5	8.70	-	-	30.4	4.35	-
T.Palur	137	68.6	-	-	-	27.7	3.65	-
Senthurai	120	65.8	4.17	5.00	-	16.7	8.33	-
Total /average	835	67.8	6.35	2.04	-	19.9	3.54	0.48

MS : Marginally saline; HSS : High SAR saline; MA : Marginally alkali; HA : Highly alkali

Table 23. Ground water quality in different blocks of Ariyalur district

Blocks	pH			EC (dS/m)			RSC (meq/l)			SAR		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Ariyalur	7.12	9.21	7.66	0.30	4.76	1.05	Nil	7.8	0.66	0.21	11.2	2.48
Thirumanur	7.04	8.92	7.70	0.31	4.15	1.12	Nil	5.6	0.43	0.18	7.2	1.46
Andimadam	7.41	8.61	7.98	0.28	1.19	0.78	Nil	2.9	0.74	0.65	6.4	3.29
Jayankondam	7.15	8.84	7.85	0.25	3.85	1.58	Nil	4.1	0.89	0.38	7.2	4.12
T.Palur	7.53	8.86	8.00	0.25	0.88	0.71	Nil	4.2	0.70	0.28	7.8	3.90
Senthurai	7.21	8.88	7.92	0.24	4.85	0.88	Nil	4.8	0.74	0.18	6.8	3.98

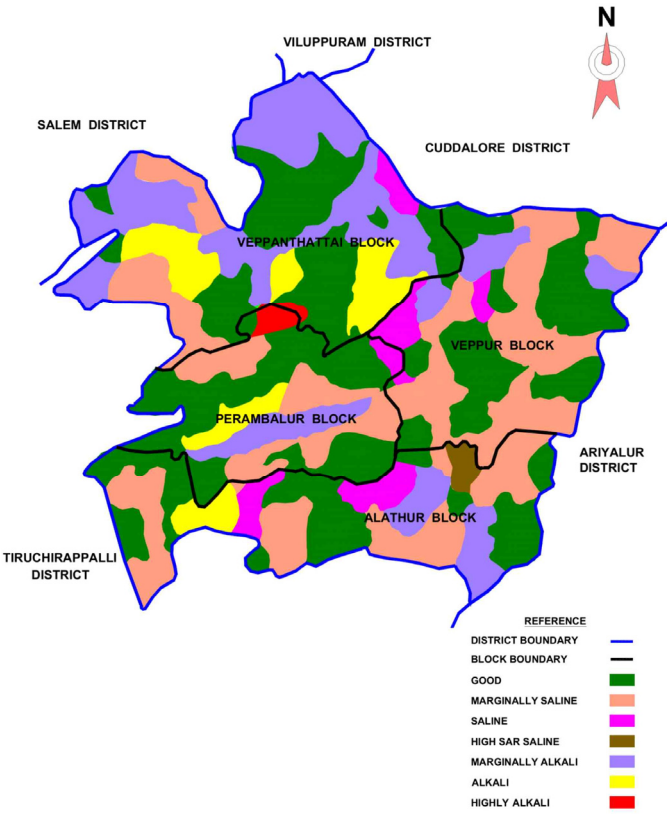


Fig. 6. Ground water quality map of Perambalur district

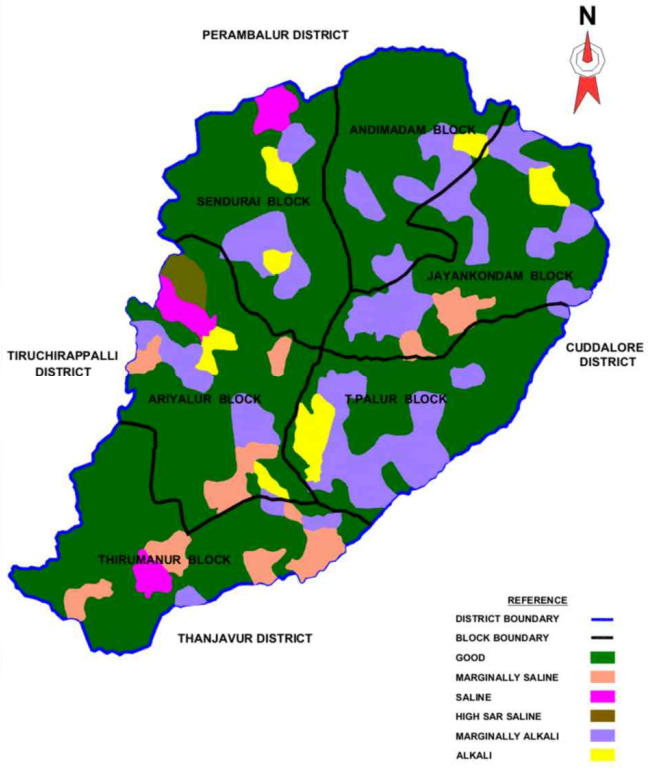


Fig. 7. Ground water quality map of Ariyalur district

Studies at Benchmark Locations in Guntur district to monitor the Changes in Ground Water Quality and Soil Properties -Bapatla

In benchmark study during 2008-09 on monitoring the changes in properties of soil and water over years, EC of the tube well water varied from 1.01 to 12.7 dS/m. The SAR values of Nidubrolu-I & II and Machavaram which have already reached unsafe levels of more than 10 continued with the same trend. During 2009-10 EC of the tube well water varied from 0.79 to 12.3 dS/m. Out of the eight locations under study, EC_{iw} of the tube well water recorded slight decrease at all locations except Chintalapudi and Chiluvuru where an increasing trend was observed by recording 2.65 dS/m and 2.54 dS/m over previous years 2.40 and 2.00 dS/m respectively (Table 24, Fig. 8).

Soil properties

The EC_e of soils at benchmark locations during 2008-09 varied in accordance with the variation in tube well waters with slight decrease at all the locations. The EC_e of the soil decreased slightly because of the heavy rains. Soils of Chiluvuru, Potharlanka, Amarthaluru and Angalakuduru were under safe limits and orchard crops like Lemon, Sapota, Turmeric, Coconut and Banana are coming up well. During 2009-10, SAR values of Nidubrolu-I & II reached levels >10 since last four years. There is marginal variation in pH, SAR and calcium content in soil samples (Table 25, Fig 9,10).

Table 24. Chemical characteristics of tube well waters at benchmark locations in Guntur district (2008-10)

Locations	Year	pH	EC (dS/m)	SAR $(mmol/l)^{1/2}$
Nidubrolu-I	1974	7.90	1.90	7.06
	2008-09	7.70	12.70	10.32
	2009-10	8.08	12.30	1.75
Nidubrolu-II	1974	7.50	1.20	5.63
	2008-09	7.76	11.60	10.25
	2009-10	7.85	11.25	2.15
Chintalapudi	1974	7.60	1.80	5.44
	2008-09	7.74	2.40	4.14
	2009-10	8.90	2.65	2.03
Machavaram	1974	7.90	1.40	4.45
	2008-09	7.42	7.90	7.76
	2009-10	8.03	7.97	4.20
Chiluvuru	2000	8.24	1.85	10.21
	2008-09	7.92	2.00	2.00
	2009-10	8.53	2.54	1.71
Potarlanka	2000	8.42	2.00	12.04
	2008-09	7.93	3.30	4.39
	2009-10	8.51	2.74	1.63
Amrutaluru	2000	8.35	2.60	15.59
	2008-09	8.38	1.91	5.48
	2009-10	9.54	1.94	3.52
Angalakuduru	2000	8.34	0.72	4.00
	2008-09	7.87	1.01	0.77
	2009-10	8.96	0.79	0.44

Table 25. Chemical composition of soils at benchmark locations irrigated with benchmarked wells

Location	Depth (cm)	pH		EC_e (dS/m)		SAR $(mmol/l)^{1/2}$	
		2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Nidubrolu-I	0-15	7.34	7.89	5.30	7.86	11.98	10.61
	15-30	7.61	7.97	5.60	6.02	10.78	10.15
	30-60	7.54	8.06	6.70	5.19	11.25	8.75
Nidubrolu-II	0-15	8.24	8.30	5.80	4.91	11.94	8.17
	15-30	8.01	8.13	5.70	5.10	11.37	7.97
	30-60	7.70	8.21	4.90	3.60	11.36	5.06
Chintalapudi	0-15	7.57	8.38	2.00	1.39	4.76	5.24
	15-30	5.10	8.09	3.00	2.03	8.08	6.40
	30-60	7.73	8.09	3.80	1.30	9.87	6.40
Machavaram	0-15	8.37	8.33	3.00	2.15	6.58	4.08
	15-30	8.19	8.45	2.90	2.67	6.10	4.88
	30-60	8.43	8.29	1.87	1.15	6.03	3.25
Chiluvuru	0-15	8.27	8.27	1.04	1.04	3.08	3.08
	15-30	8	8.00	1.21	1.21	3.83	3.83
	30-60	7.77	8.34	1.43	0.80	4.04	2.59
Potarlanka	0-15	8.24	8.46	1.43	1.76	4.42	4.91
	15-30	8.28	8.37	1.59	1.36	4.94	6.21
	30-60	8.28	8.34	1.54	0.62	4.33	0.61
Amrutaluru	0-15	8.32	8.42	1.25	0.71	4.89	3.11
	15-30	8.01	8.29	1.88	0.99	6.64	4.11
	30-60	8.13	8.54	1.93	0.79	7.53	2.22
Angalakuduru	0-15	8.12	9.49	0.45	1.03	1.33	1.09
	15-30	8.13	8.64	0.31	0.66	0.62	1.42
	30-60	8.25	8.34	0.36	0.54	0.00	1.96

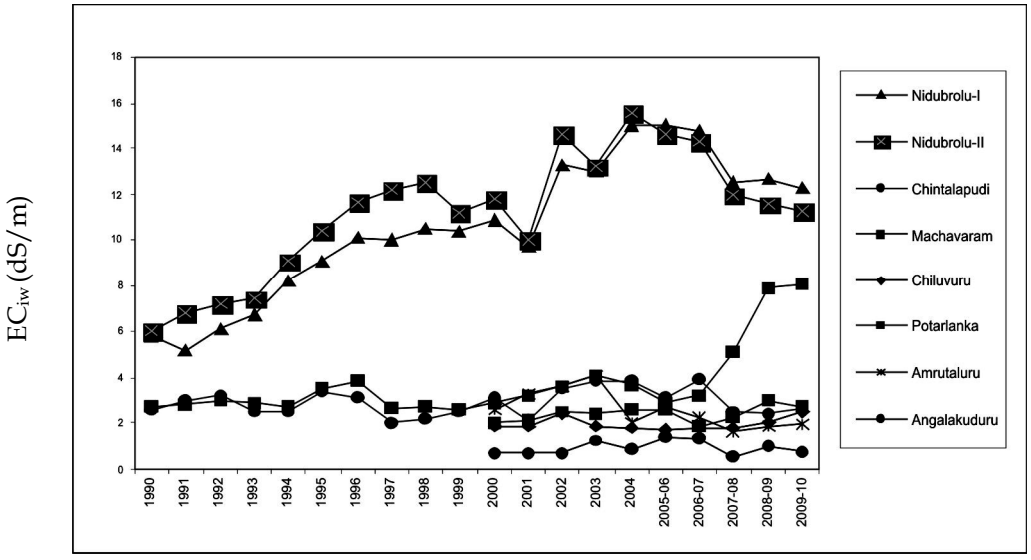


Fig. 8. Yearly fluctuation in EC of ground water at benchmark locations in Guntur district, A.P. (1974-2009-10)

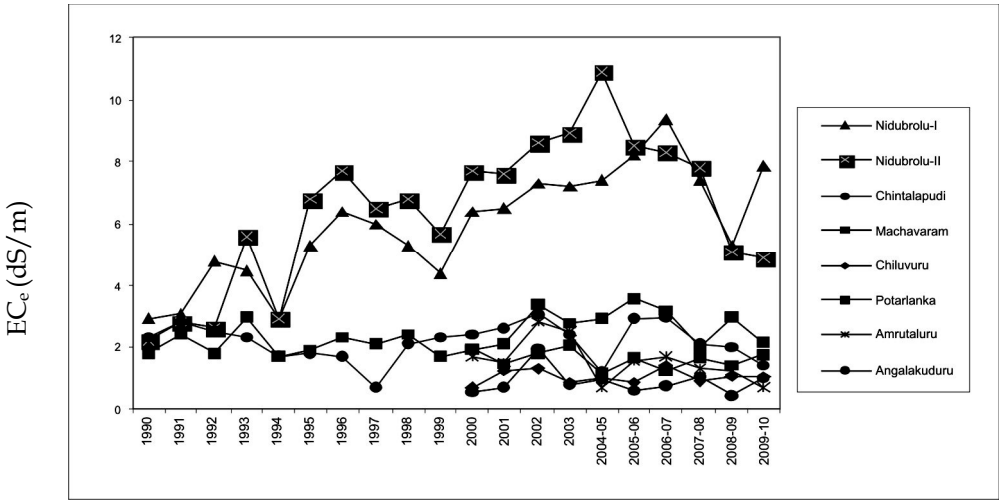


Fig. 9. Yearly fluctuation in salt build-up at 0-15 cm depth due to use of ground water in benchmark locations of Guntur districts, A.P. (1990-2009-10)

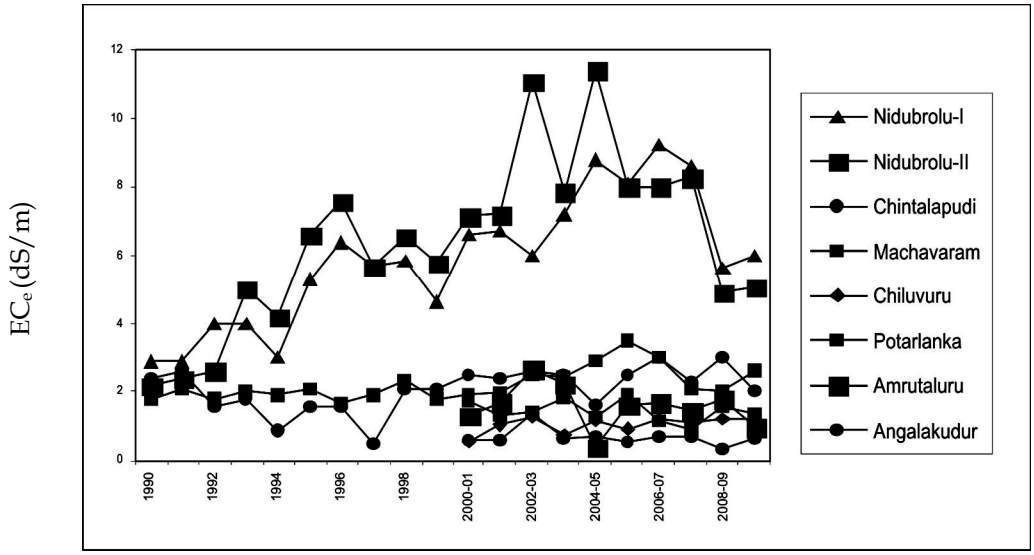


Fig. 10. Yearly fluctuation in salt build-up at 15-30 cm depth due to use of ground water in benchmark locations of Guntur districts, A.P. (1990-2009-10)

Effect of Saline Water Irrigation on Crop Yield and Soil Properties -Agra

The experiment was conducted in micro plots (2.5 x 2.5 m) separated by polythene sheets up to 90 cm depth. The SAR of irrigation water was 10 $(mmol/l)^{1/2}$.

From 2009, non-convention crops viz. Tulsi (variety-Rama), Isabgol (variety-Mayur), Fennel (variety-Local) and Fenugreek (variety-Sag Kalami) were grown to assess the tolerance for salinity. The results of the experiment showed that biomass of Tulsi and seed yield of Isabgol declined significantly at EC_{iw} 6 dS/m, whereas the grain yield of fennel declined at EC_{iw} 4 dS/m as compared to best available water (EC_{iw} 2.5 dS/m). However, no significant difference was observed in grain yield of fenugreek at different EC_{iw} levels over best available water (Table 26).

Table 26. Effect of saline water on tulsi, isabgol, fennel and fenugreek (t/ha)

Treatments	Tulsi (biomass)	Isabgol (seed yield)	Fennel (seed yield)	Fenugreek (seed yield)
EC_{iw} (dS/m)				
BAW	21.30	0.70	0.42	1.12
4	20.53	0.63	0.31	0.98
6	18.76	0.53	0.29	0.94
8	18.64	0.31	0.28	0.92
CD (5%)	1.92	0.14	0.09	0.43

EC of BAW: 2.5 dS/m

Soil salinity

Soil salinity increased with salinity of water and number of irrigations. During *rabi* season soil salinity increased in different layers as compared to *kharif* season (Table 27)

Table 27. Effect of different treatments on soil salinity at sowing and harvest of crops (0-30 cm)

Treatments	Soil Depth (cm)	Tulsi		Isabgol		Fennel		Fenugreek	
		AS	AH	AS	AH	AS	AH	AS	AH
EC_{iw} (dS/m)									
BAW	0-15	1.7	1.8	3.4	4.9	3.7	4.7	2.6	3.4
	15-30	1.6	1.6	3.2	3.4	4.3	4.3	2.1	2.7
	30-60	1.5	1.7	2.6	3.0	4.1	4.0	1.5	2.2
4	0-15	2.6	3.4	6.0	7.6	5.6	6.5	4.5	5.5
	15-30	2.2	3.4	3.4	5.6	6.0	5.2	4.2	4.6
	30-60	1.8	1.8	3.2	3.6	5.4	5.0	2.6	2.9
6	0-15	2.6	3.7	7.6	11.0	7.3	8.2	5.4	6.3
	15-30	2.3	2.5	6.0	7.3	7.2	7.1	4.5	4.8
	30-60	2.0	2.3	5.4	5.5	6.2	6.6	2.9	3.0
8	0-15	4.0	5.0	8.6	11.3	10.0	12.3	4.4	7.0
	15-30	3.0	3.2	7.2	6.9	9.7	11.5	4.5	4.6
	30-60	2.1	2.2	5.4	6.2	7.4	7.2	3.0	3.2

AS: At sowing; AH: At harvest

Conjunctive Use of Alkali/Canal Waters -Agra

A field experiment was initiated during 2003 to evaluate the effect of different irrigation modes for the combination use of canal and alkali water (RSC 15 meq/l) under different cyclic and mixing modes for potato – sunflower crop rotation. *Dhaincha* was grown for green manuring during rainy season as rainfed crop in all the treatments. The treatment combination were: T_1 - All canal water (control), T_2 - One year canal : Two year alkali, T_3 - Two year alkali : One year canal , T_4 - Two year canal : One year alkali, T_5 - One year alkali : Two year canal , T_6 - All alkali (potato) : All canal (sunflower), T_7 - Mixing (one canal + two alkali), T_8 - Mixing (two canal + one alkali) and T_9 - All alkali. The data indicated that use of alkali water alone significantly reduced the yield of potato and sunflower although the adverse effects were comparatively less pronounced during first year (Table 28). The yield of all the crops improved under various combinations of CW and AW. When averaged over 6 years, the relative yield (RY) of potato was 67, 54, 78, 61 and 48% under cyclic mode (1yCW:2yAW, 1yAW:2yCW, 2yCW:1yAW, 1yAW:2yCW and AWp:CWs) treatments, respectively,

while the RY was 83 and 58% for waters blended in the ratio of 2CW:1AW and 1CW:2AW, respectively. Similarly, the relative yield of sunflower was 60, 55, 73, 56 and 60% for cyclic mode and 78 and 52% with blended waters. In general, both the crops tended to perform better with cyclic than blending. Although theoretically one might expect better performance with alkali water in blending mode. The *Sesbania* crop was grown with monsoon rainwater but responded to sodicity build-up associated with previous crops.

Table 28. Effect of modes of irrigation with canal and alkali waters on yield (t/ha) of crops

Treat.	2003-04		2004-05		2005-06		2006-07		2007-08		2008-09		Mean	
	Potato	SF	Potato	SF	Potato	SF	Potato	SF	Potato	SF	Potato	SF	Potato	SF
T_1	24.5	1.3	28.2	1.5	25.9	1.2	31.2	1.5	25.7	1.1	36.3	1.3	28.6	1.3
T_2	23.1	1.2	17.9	0.7	10.6	0.5	23.6	1.2	16.0	0.6	17.3	0.6	19.1	0.8
T_3	18.8	0.8	10.8	0.7	18.4	0.8	13.7	0.7	8.40	0.6	20.8	0.8	15.5	0.7
T_4	19.7	1.0	24.1	1.4	20.9	0.6	24.9	1.1	23.4	1.0	22.9	0.7	22.4	0.9
T_5	9.3	0.5	16.8	1.0	15.9	1.0	13.7	0.6	14.0	0.7	31.1	0.7	17.3	0.7
T_6	11.4	0.8	13.5	1.0	16.5	0.7	12.7	0.8	09.4	0.7	19.6	0.8	13.8	0.8
T_7	13.8	0.8	15.3	0.7	17.0	07	16.6	0.7	12.9	0.6	24.4	0.6	16.7	0.7
T_8	21.0	1.0	22.4	13	21.7	0.9	24.0	1.1	21.3	0.9	31.8	0.9	23.7	1.0
T_9	7.1	0.3	4.3	0.2	3.4	0.1	2.60	0.2	2.3	0.1	6..5	0.1	4.4	0.1
CD(5%)	1.8	0.2	2.1	0.2	1.6	0.2	2.1	0.1	2.3	0.4	1.9	0.1	-	-

SF : Sunflower; T_1 - All canal water (control), T_2 - One year canal : Two year alkali, T_3 - Two year alkali : One year canal , T_4 - Two year canal : One year alkali, T_5 - One year alkali : Two year canal , T_6 - All alkali (potato) : All canal (sunflower), T_7 - Mixing (one canal + two alkali), T_8 - Mixing (two canal + one alkali) and T_9 - All alkali.

The per cent oil content differed significantly amongst the treatments (Table 29). The maximum oil content was recorded with all canal water and the minimum with alkali water which was 2-3% less as compared to canal water.

Table 29. Oil content in grains of sunflower

Treatments	Oil content (%)						
	2004	2005	2006	2007	2008	2009	Mean
T_1	42.2	42.3	41.8	42.2	42.1	42.2	42.1
T_2	41.7	40.0	39.5	39.9	38.9	39.1	39.9
T_3	40.8	39.7	39.9	39.5	38.7	39.2	39.6
T_4	41.0	41.5	40.2	39.6	38.5	39.1	39.9
T_5	39.6	40.5	38.6	38.7	37.7	38.2	38.9
T_6	40.7	40.6	39.8	39.7	38.9	39.1	39.6
T_7	41.0	40.2	39.7	39.8	38.7	39.1	39.8
T_8	41.7	41.5	40.5	40.2	39.9	40.5	40.7
T_9	38.6	38.3	37.8	36.9	35.9	36.3	37.3
CD (5%)	1.4	1.5	1.4	1.4	1.5	1.4	-

Notation same as given in Table 28

Soil chemical properties

Analysis of pooled data revealed that the EC_e varied from 2.7 to 4.7 dS/m after harvest of potato which remained almost at the same level after harvest of sunflower. With alkali water irrigation, ESP increased such that it was 9.7 in all canal and 25.4 in all alkali water after harvest of potato. In case of alkali water, ESP further increased to 36.4 after harvest of sunflower. The ESP was higher in 0-30 cm as compared to surface (0-15 cm) depth (Table 30).

Table 30. Effect of conjunctive modes on EC, pH and ESP of soil (Av. 6 years)

Treatments	Depth (cm)	Sowing			Harvest					
		Potato			Potato			Sunflower		
		EC_e	pH	ESP	EC_e	pH	ESP	EC_e	pH	ESP
T_1	0-15	2.6	7.6	8.9	2.7	7.6	9.7	2.8	7.6	10.9
	15-30	2.5	7.6	9.5	2.7	7.6	10.1	2.6	7.6	11.2
T_2	0-15	3.4	8.1	13.2	3.6	8.1	15.1	3.5	8.2	16.7
	15-30	3.5	8.2	15.4	3.6	8.1	16.1	3.5	8.2	19.2
T_3	0-15	3.7	8.3	15.0	3.8	8.4	17.5	3.6	8.2	20.3
	15-30	3.6	8.3	17.5	3.6	8.4	19.8	3.5	8.2	23.7
T_4	0-15	3.5	8.1	13.5	3.3	8.2	12.3	3.6	8.3	15.2
	15-30	3.4	8.1	14.9	3.4	8.2	13.6	3.5	8.3	17.6
T_5	0-15	4.1	8.3	13.9	3.9	8.4	15.6	3.9	8.1	16.8
	15-30	3.9	8.3	15.9	3.8	8.4	18.2	3.7	8.1	19.5
T_6	0-15	3.5	8.3	13.2	3.5	8.4	15.2	3.6	8.4	14.9
	15-30	3.4	8.3	15.1	3.5	8.3	16.9	3.6	8.3	16.6
T_7	0-15	3.6	8.6	16.0	3.6	8.5	16.7	3.6	8.3	20.2
	15-30	3.5	8.5	17.7	3.5	8.5	19.7	3.4	8.2	23.8
T_8	0-15	3.4	8.5	13.7	3.4	8.3	13.7	3.5	8.2	14.7
	15-30	3.4	8.4	15.4	3.3	8.3	15.7	3.4	8.1	18.5
T_9	0-15	4.7	9.0	22.5	4.7	8.9	25.4	4.8	9.1	36.4
	15-30	4.5	8.8	25.7	4.5	8.8	31.1	4.6	9.0	42.7

Notation same as given in Table 28

Conjunctive Use of Canal and Alkali Water in Rice Based Cropping Systems - Tiruchirapalli

Field experiment was initiated during 2008 to study the conjunctive use of canal and alkali water with different rice planting methods and to find out a profitable vegetable crop grown after rice in alkali soil. The experiment was laid out in alkali soil (pH – 8.7, EC – 0.21 dS/m, ESP – 25.0). Rice was grown during *rabi* (October – January) and vegetables during summer period (March – June). The canal water (EC 0.6 dS/m, SAR 1.3 and RSC 1.4 meq/l), alkali water (EC 1.8 dS/m, SAR 8.2 and RSC 6.9 meq/l) was used for the study. The treatment details* of the experiment are given as follows:

Main plot treatments: Irrigation (3)

M_1: Irrigating both rice and vegetables with alkali water; M_2: Irrigating rice with canal water and vegetables with alkali water; M_3: Irrigating rice with canal water and alkali water in 1:1 ratio (cyclic) and vegetables with alkali water.

Planting method (4)

S_1: Conventional planting (Random); S_2: Line planting
S_3: Square planting (SRI); S_4: Machine planting

The main plots after rice harvest were divided into 7 subplots and the treatments were imposed as follows:

Subplot: Vegetable crops (7)
S_1: Okra; S_2: Cluster bean; S_3: Baby corn; S_4: Cucumber; S_5: Brinjal; S_6: Tomato; and S_7: Amaranthus

Significant differences were observed for irrigation treatments and methods of planting. Regarding the irrigation treatments, canal water irrigation for rice recorded the maximum yield of 5.77 t/ha and 6.21 t/ha (2008-2009 and 2009-2010) followed by cyclic irrigation of canal water and alkali water in 1:1 ratio (Table 31). Lowest yield was recorded in alkali water irrigation. In respect of method of planting, adopting square planting registered the maximum grain yield of 5.82 and 6.03 t/ha (2008-2009 and

2009-2010) followed by line planting. In both years highest yield of 6.41 t/ha and 6.76 t/ha was recorded with canal water irrigation adopted with square planting followed by canal water irrigation with line planting. Mixing mode of canal water and alkali water (1:1) with square planting recorded 23.0% and 34.9% more yield than the alkali water irrigation with conventional planting.

Among the different vegetable crops grown during summer after the harvest of rice crop (Table 32 and Table 33), brinjal registered the highest yield of 25.3 t/ha and 22.8 t/ha in the canal water irrigation with highest income of Rs. 1.52 lakh/ha and 2.28 lakh/ha during 2008-2009 and 2009-2010.

Post harvest analysis of soil samples revealed that the highest soil pH of 9.0 and 9.12, EC of 0.19 dS/m and 0.24 dS/m and soil ESP build up of 34.1% and 31.3% were in continuous use of alkali water for both rice and vegetables during the year 2008-09 and 2009-10 respectively (Table 34). Different method of planting and cultivation of different vegetables as follow up crop had no significant effect on soil properties at harvest stage.

Table 31. Grain yield of rice as influenced by different irrigation and planting methods

Irrigation	2008					2009				
treatment	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
M_1	4.69	4.95	5.28	4.71	4.91	4.52	4.90	5.21	4.81	4.86
M_2	4.81	6.00	6.41	5.85	5.77	5.62	6.32	6.76	6.12	6.20
M_3	4.75	5.43	5.78	5.31	5.32	5.12	5.82	6.11	5.32	5.59
Mean	4.75	5.46	5.82	5.29		5.09	5.68	6.03	5.42	
	M	S	MxS	SxM		M	S	MxS	SxM	
CD (5%)	0.144	0.119	0.229	0.207		0.245	0.168	0.351	0.291	

Treatments as explained in the text

Table 32. Effect of irrigation and method of planting on yield and income of vegetables (2008-2009)

Treatment	Vegetable crops	Yield (t/ha)	Income (Rs./ha)
M_1S_1	AW + Okra	6.59	52728
M_1S_2	AW + Cluster bean	4.54	27222
M_1S_3	AW + Baby corn	0.35	17650
M_1S_4	AW + Cucumber	9.14	45690
M_1S_5	AW + Brinjal	20.42	122514
M_1S_6	AW + Tomato	0.00	0
M_1S_7	AW + Amaranthus	0.67	3365
M_2S_1	CW + Okra	8.25	65968
M_2S_2	CW + Cluster bean	6.12	36744
M^2S_3	CW + Baby corn	0.62	30900
M_2S_4	CW + Cucumber	12.42	62100
M_2S_5	CW + Brinjal	25.32	151896
M_2S_6	CW + Tomato	0.00	0
M_2S_7	CW + Amaranthus	1.21	6070
M_3S_1	CW & AW + Okra	7.01	56104
M_3S_2	CW & AW + Cluster bean	5.21	31236
M_3S_3	CW & AW + Baby corn	0.53	26450
M_3S_4	CW & AW + Cucumber	10.96	54780
M_3S_5	CW & AW + Brinjal	23.98	143904
M_3S_6	CW & AW + Tomato	0.00	0
M_3S_7	CW & AW + Amaranthus	0.91	4540

AW : Alkali water; CW : Canal water; CW & AW : Canal water & Alkali water (Cyclic mode)

For increasing rice yield in alkali soil, cyclic mode of canal water and alkali water (1:1) irrigation with square planting (SRI method) may be adopted. In rice-vegetable cropping system during summer period brinjal may be successfully grown with alkali water with higher profitability. Thus, conjunctive use of canal water for rice under square planting (SRI method) and alkali water for vegetables resulted in significantly higher yield of crops in rice - vegetable cropping system.

Table 33. Effect of irrigation and method of planting on yield of vegetables and income (2009-2010)

Treatments	Vegetable crops	Yield (t/ha)	Income (Rs./ha)
M_1S_1	AW + Okra	6.12	48960
M_2S_1	CW + Okra	8.65	69200
M_3S_1	CW & AW + Okra	7.8	62400
M_1S_2	AW + Brinjal	18.1	181000
M_2S_2	CW + Brinjal	22.8	228000
M_3S_2	CW & AW + Brinjal	20.3	203000
M_1S_3	AW + Cluster bean	4.16	16640
M_2S_3	CW + Cluster bean	6.56	26240
M_3S_3	CW & AW + Cluster bean	5.72	22880
M_1S_4	AW + Vegetable cowpea	3.36	20160
M_2S_4	CW + Vegetable cowpea	4.64	27840
M_3S_4	CW & AW + Vegetable cowpea	4.15	24900

Notations have same meaning as in Table 32

Table 34. Effect of conjunctive mode and method of planting on post harvest soil properties

Irrigation treatment	pH									
	2008-09					2009-10				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
M_1	9.0	9.1	8.9	9.0	9.0	9.0	9.0	9.1	9.1	9.1
M_2	8.1	8.2	8.1	8.2	8.2	8.6	8.6	8.6	8.6	8.6
M_3	8.5	8.7	8.4	8.3	8.5	8.6	8.7	8.7	8.6	8.7
Mean	8.5	8.6	8.5	8.5		8.7	8.8	8.8	8.8	
	M	S	MxS	SxM		M	S	MxS	SxM	
CD (5%)	0.1	NS	NS	NS		0.30	NS	NS	NS	
					EC					
M_1	0.18	0.19	0.18	0.20	0.19	0.19	0.2	0.18	0.21	0.20
M_2	0.15	0.14	0.15	0.15	0.15	0.16	0.15	0.16	0.14	0.15
M_3	0.17	0.16	0.17	0.15	0.16	0.18	0.16	0.17	0.17	0.17
Mean	0.17	0.16	0.17	0.17		0.18	0.17	0.17	0.17	
	M	S	MxS	SxM		M	S	MxS	SxM	
CD (5%)	0.03	NS	NS	NS		0.08	NS	NS	NS	
					ESP					
M_1	34.1	33.9	34.4	34.0	34.1	31.8	29.6	30.1	33.8	31.3
M_2	21.3	22.5	21.5	21.1	21.6	19.0	19.8	20	21.2	20.0
M_3	26.5	27.7	26.8	26.3	26.8	24.6	25.2	26.1	24.9	25.2
Mean	27.3	28.0	27.6	27.1		25.1	24.9	25.4	26.6	
	M	S	MxS	SxM		M	S	MxS	SxM	
CD (5%)	1.38	NS	NS	NS		1.2	NS	NS	NS	

Effect of High RSC Water along with FYM and Gypsum in Vegetables – Hisar

In the year 2008-09, the study on use of sodic water in broccoli-cluster bean and knol khol-ridge gourd vegetables in relation to gypsum as an amendment and FYM was carried out at vegetable farm of CCS HAU, Hisar in micro-plots of size 3.0 m x 3.0 m and 3.6m x 3.6 m, respectively. Whereas, during 2009-10, it was carried out on broccoli-cluster bean and okra-cabbage vegetables. In broccoli-cluster bean, levels of gypsum application were three (0, 50 and 100 per cent neutralization of RSC water) and five in knol khol-ridge gourd and okra-cabbage (0, 25, 50, 75 and 100 neutralization of RSC water). In both experiments, there were three levels of FYM (0, 10 and 20 t/ha represented as F_0, F_1 and F_2, respectively). The crops were irrigated with sodic water having average RSC 11.5 meq/l and SAR 14.0 $(mmol/l)^{1/2}$. The requisite amount of gypsum in various treatments was applied in a single dose before sowing of crop and mixed well in the soil. Irrigation schedule was based on the recommendations for the non-saline irrigated soils. The ionic composition of irrigation water is given in Table 35.

Table 35. Ionic composition and quality parameters of irrigation water

Ion/parameter	Values
CO_3 (meq/l)	0.7
HCO_3 (meq/l)	13.3
Ca (meq/l)	1.0
Mg (meq/l)	1.5
Na (meq/l)	15.8
Cl (meq/l)	4.0
SO_4 (meq/l)	6.0
EC_{iw} (dS/m)	2.4
RSC_{iw} (meq/l)	11.5
SAR_{iw} $(mmol/l)^{1/2}$	14.0

During 2008-09, the cluster bean yield increased significantly with the addition of both FYM and gypsum (Table 36). The highest yield of 13.07 t/ha was observed in F_2G_2 and the lowest (0.20 t/ha) in F_0G_0 treatment.

Table 36. Effect of FYM and gypsum on the yield (t/ha) of cluster bean with sodic water

Treatments	Gypsum (per cent GR)			Mean
	G_0	G_1	G_2	
FYM (t/ha)				
F_0	0.20	9.99	10.31	6.83
F_1	0.58	10.73	12.02	7.78
F_2	0.73	12.17	13.07	8.66
Mean	0.50	10.96	11.80	
CD (5%)	Gypsum : 0.77; FYM: 0.77; G x FYM : NS			

F_0 : 0; F_1: 10 and F_2: 20 t/ha FYM, *G_0 : 0; G_1 : 50 and G_2 : 100 % neutralization of RSC water*

During 2008-09, the yield (t/ha) of broccoli was significantly increased with the addition of gypsum and FYM when irrigated with sodic water (RSC 11.5 meq/l). The highest yield of 10.60 t/ha was observed in F_2G_2 treatment and the lowest (0.32 t/ha) was recorded in F_0G_0 treatment as shown in Table 37.

Table 37. Effect of FYM and gypsum on the yield (t/ha) of broccoli with sodic water

Treatments	Gypsum (per cent GR)			Mean
	G_0	G_1	G_2	
FYM (t/ha)				
F_0	0.32	3.90	4.82	3.01
F_1	1.23	6.07	9.16	5.49
F_2	2.35	9.82	10.60	7.59
Mean	1.30	6.60	8.19	
CD (5%)		Gypsum: 1.30	FYM: 1.30	G x FYM: NS

Notations are same as given in Table 36

The pH of soil decreased with the addition of FYM and gypsum (Fig. 11). The reduction with gypsum application was more pronounced as that of FYM. The maximum pH value of 10.03 was recorded in F_0G_0 treatment in 15-30 cm soil depth which resulted in very poor yield of the crop. However, the lowest value of 7.97 was obtained in F_2G_2 treatment in 0-15 cm soil depth due to the 100 per cent neutralization of the RSC with gypsum.

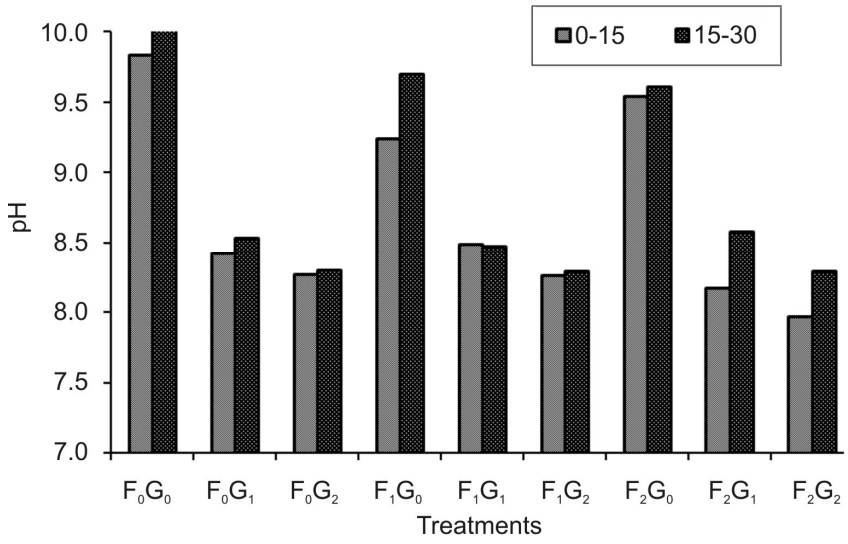


Fig. 11. Effect of different combination of gypsum and FYM on soil pH after broccoli irrigated with sodic water

During 2009-10, the yield of cluster bean increased significantly both with the addition of gypsum and FYM irrigated with sodic water (RSC11.6 meq/l). In cluster bean, the highest yield of 9.13 t/ha was obtained in F_2G_2 treatment and the lowest (0.45 t/ha) was recorded in F_0G_0 treatment (Table 38).

Table 38. Effect of FYM and gypsum on the yield (t/ha) of cluster bean under sodic water irrigation

Treatments	Gypsum (per cent GR)			Mean
	G_0	G_1	G_2	
FYM (t/ha)				
F_0	0.45	4.83	6.06	3.78
F_1	0.73	6.18	8.22	5.05
F_2	0.82	6.96	9.13	5.64
Mean	0.67	5.99	7.80	
CD (5%)		Gypsum : 0.38	FYM : 0.38	G x FYM : 0.65

Notations are same as given in Table 36

During 2009-10, in broccoli also, yield increased significantly with the addition of both gypsum and FYM. The highest yield of 10.70 t/ha was observed in F_2G_2 treatment and the lowest (0.33 t/ha) was recorded in F_0G_0 treatment (Table 39).

Table 39. Effect of FYM and gypsum on the yield (t/ha) of broccoli under sodic water irrigation

Treatments	Gypsum (per cent GR)			Mean
	G_0	G_1	G_2	
FYM (t/ha)				
F_0	0.33	4.32	5.55	3.40
F_1	1.51	6.25	8.96	5.57
F_2	2.06	9.87	10.70	7.55
Mean	1.30	6.81	8.40	
CD (5%)	Gypsum : 0.28	FYM : 0.28	G x FYM : 0.48	

Notations are same as given in Table 36

In bitter guard, the mean yield increased by 78 and 117 per cent with F_1 and F_2 as compared to F_o, respectively (Table 40). The mean yield increased significantly with the addition of gypsum and 18 times increase in G_4 was observed as compared to G_0.

Table 40. Effect of FYM and gypsum on the yield of bitter gourd (t/ha) under sodic water

Treatments	Gypsum (per cent GR)					Mean
	G_0	G_1	G_2	G_3	G_4	
FYM (t/ha)						
F_0	0.10	0.59	0.85	1.21	1.47	0.84
F_1	0.12	1.29	1.47	2.19	2.45	1.50
F_2	0.18	1.47	2.06	2.37	3.01	1.82
Mean	0.13	1.11	1.46	1.92	2.31	
CD (5%)		Gypsum : 0.15	FYM : 0.11	G x FYM : 0.26		

F_0 : 0; F_1: 10 and F_2: 20 t/ha FYM, *G_0 : 0; G_1 : 25 and G_2 : 50;* G_3 : 75 and G_4 : 100% *neutralization of RSC water*

The curd weight of knol-khol (t/ha) increased significantly with the addition of gypsum and FYM (Table 41). However, the magnitude of increase was higher with gypsum than FYM. The mean yield of knol-khol increased from 1.91 t/ha under no gypsum to 10.68 t/ha under 100 per cent GR. Maximum yield (10.43 t/ha) of knol-khol was obtained in F_2G_4 treatment.

Table 41. Effect of FYM and gypsum on the yield (t/ha) of knol-khol with sodic water

Treatments	Gypsum (per cent GR)					Mean
	G_0	G_1	G_2	G_3	G_4	
FYM (t/ha)						
F_0	1.80	5.20	7.10	8.13	9.73	6.39
F_1	1.97	6.23	9.00	10.00	10.73	7.59
F_2	1.97	7.80	9.70	10.43	11.57	8.29
Mean	1.91	6.41	8.60	9.52	10.68	
CD (5%)		Gypsum : 0.49	FYM : 0.38	G x FYM : 0.84		

Notations are same as given in Table 40

The pH of the soil decreased both with the addition of gypsum and FYM. In 0-15 cm layer, the highest pH of 9.44 was observed in G_0F_0 treatment while the lowest of 8.27 in G_4F_2 treatment after the harvesting of knol-khol crop (Fig. 12).

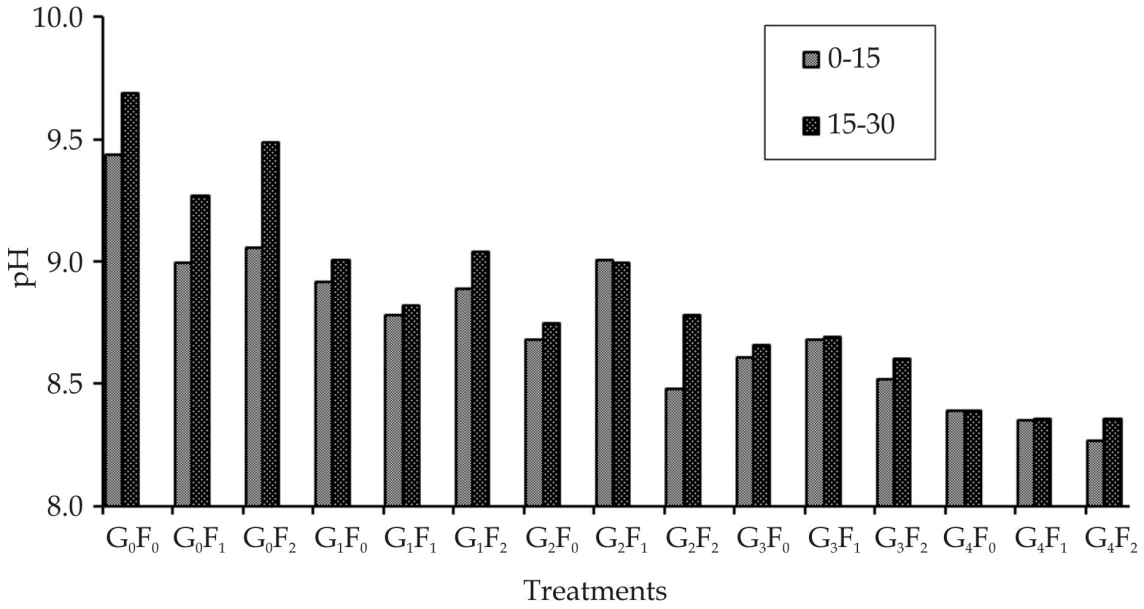


Fig. 12. Effect of different combination of gypsum and FYM on soil pH after knol-khol irrigated with sodic water

The ESP of the soil decreased with the addition of gypsum and FYM (Fig. 13). The reduction with gypsum application was more pronounced as compared to FYM. The maximum ESP value of 40.1 was recorded in F_0G_0 treatment. However, the lowest value of 11.1 was obtained in F_2G_4 treatment in 0-15 cm soil depth.

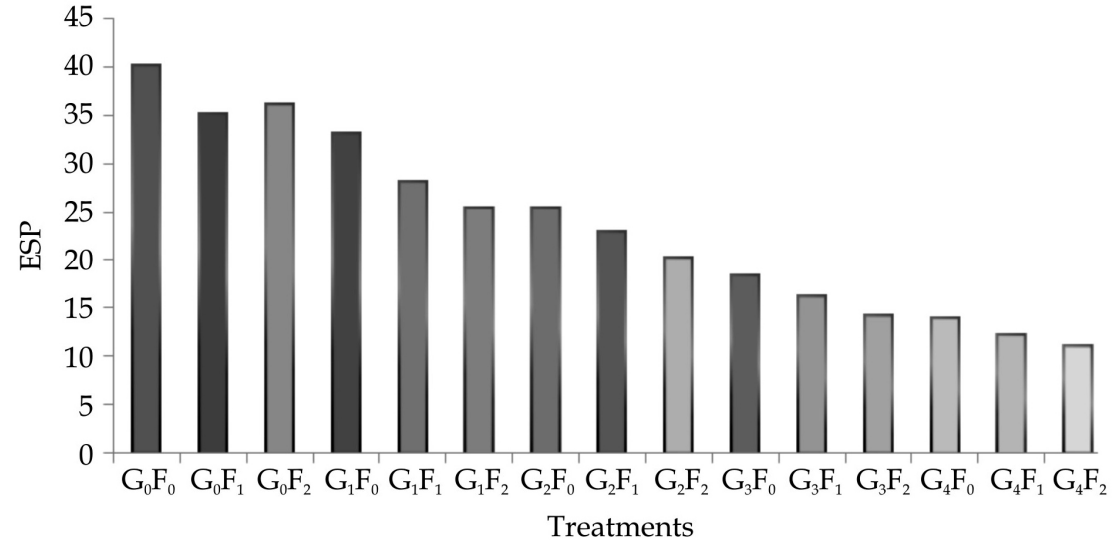


Fig. 13. Effect of different combination of gypsum and FYM on soil ESP after knol-khol irrigated with sodic water

During 2009-10, the yield of okra increased significantly both with the addition of gypsum and FYM irrigated with sodic water (RSC 11.5 meq/l). However, the magnitude of increase was higher with gypsum than FYM. Maximum yield (9.52 t/ha) of okra was obtained in F_2G_4 treatment. The yield increased by 18 and 22 percent with F_1 and F_2 as compared to F_0 (Table 42). The mean yield increased significantly with the addition of gypsum and 2 times increase was observed in G_4 as compared to G_0.

Table 42. Effect of FYM and gypsum on the yield of okra (t/ha) under sodic water

Treatments	Gypsum (per cent GR)					Mean
	G_0	G_{25}	G_{50}	G_{75}	G_{100}	
FYM (t/ha)						
F_0	4.63	5.66	5.92	6.43	6.94	5.92
F_{10}	4.37	6.43	7.20	7.97	9.00	7.00
F_{20}	3.86	6.69	7.46	8.49	9.52	7.20
Mean	4.29	6.26	6.86	7.63	8.49	
CD (5%)	Gypsum : 0.22 ; FYM : 0.17; G x FYM : 0.38					

Notations are same as given in Table 40

During 2009-10, the curd weight of cabbage also increased significantly with the addition of gypsum and FYM (Table 43). The mean yield increased from 17.53 t/ha under no gypsum to 25.95 t/ha under 100 per cent GR. Maximum yield (27.43 t/ha) of cabbage was obtained in F_2G_4 treatment.

Table 43. Effect of FYM and gypsum on the yield of cabbage (t/ha) under sodic water

Treatments	Gypsum (per cent GR)					Mean
	G_0	G_{25}	G_{50}	G_{75}	G_{100}	
FYM (t/ha)						
F_0	16.54	17.73	20.41	23.34	24.12	20.43
F_{10}	17.50	18.93	21.22	25.04	26.29	21.80
F_{20}	18.53	19.84	23.79	26.25	27.43	23.17
Mean	17.53	18.83	21.81	24.88	25.95	
CD (5%)	Gypsum : 0.71 ; FYM : NS ; G x FYM : 1.22					

Notations are same as given in Table 40

The pH of the soil decreased both with the addition of gypsum and FYM. In 0-15 cm layer, the highest pH of 9.40 was observed in G_0F_0 treatment and the lowest was 8.30 in G_4F_2 treatment (Fig. 14) after the harvesting of cabbage.

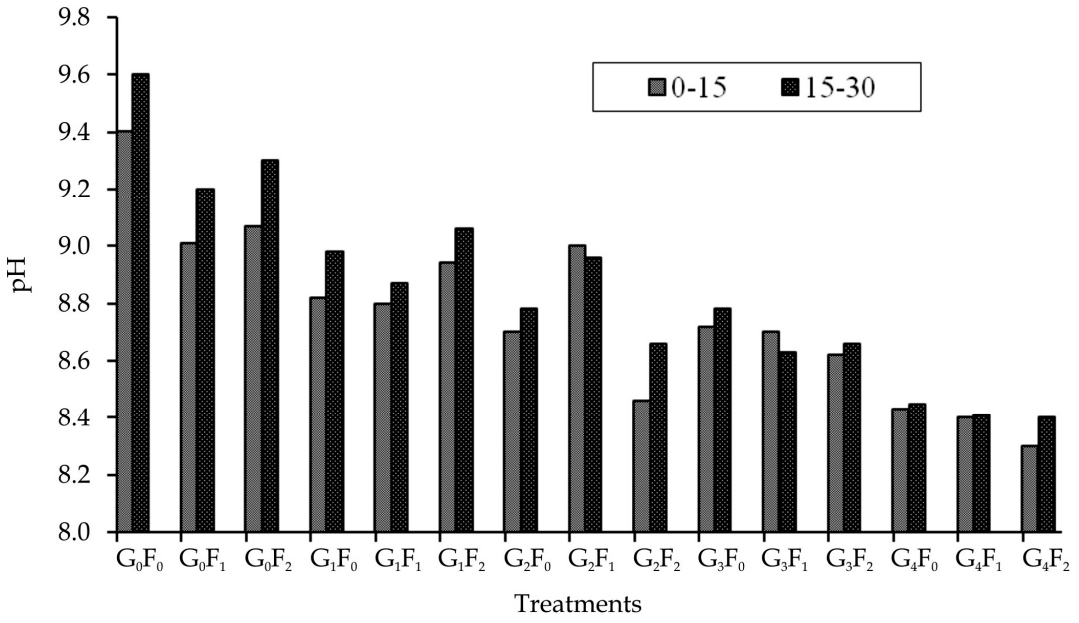


Fig. 14. Effect of different combination of gypsum and FYM on soil pH after cabbage

Management of High RSC Waters in Heavy Textured Soils - Bapatla

Pot experiment was conducted during 2009-10 to find out the best amendment to mitigate the effect of High RSC water on cluster bean. Pyrites and gypsum were applied 25 days before sowing. Phospho-gypsum (S_2) was found to be the best in increasing the pod yield followed by pyrites (S_3), FYM (S_4), pressmud cake (S_5) and aluminium sulphate (S_6) over control (S_1). Phospho-gypsum applied with RSC 5 meq/l water recorded highest pod yield (371.2 g/pot) while lowest yield was recorded in control. Significant differences in pod yield were observed with pyrites (S_3) at varying RSC levels (Table 44). Yield decreased with increasing levels of RSC in water irrespective of the amendments. Similar trend was also observed in case of drymatter yield (Table 45).

Table 44. Effect of RSC water on cluster bean pod yield (g/pot)

	S_1	S_2	S_3	S_4	S_5	S_6	Mean
RSC (meq/l)							
5	231.0	371.2	323.0	287.1	271.8	255.8	290.0
10	206.0	359.4	303.6	280.3	268.4	243.6	276.9
15	142.8	338.4	297.2	275.1	261.0	239.3	259.0
Mean	193.3	356.3	307.9	280.8	267.1	246.2	
	Main	Sub	Interaction				
S Em	1.800	2.600	4.500				
CD (5%)	5.235	7.403	14.073				
CV	2.811						

S_1 : control; S_2 : phosphogypsum; S_3 : pyrites; S_4 :FYM; S_5 : press mud cake; S_6 : aluminium sulphate

Table 45. Effect of RSC water on cluster bean dry matter yield (g/pot)

	S_1	S_2	S_3	S_4	S_5	S_6	Mean
RSC (meq/l)							
5	20.21	33.55	29.15	27.12	25.16	23.32	26.42
10	18.31	30.32	28.64	26.47	24.76	22.90	25.23
15	16.52	29.62	28.09	25.75	24.30	22.24	24.42
Mean	18.35	31.16	28.63	26.45	24.74	22.82	
	Main	Sub	Interaction				
S Em	0.800	0.120	0.200				
CD (5%)	2.34	0.331	0.629				
CV	1.365						

Notations are same as given in Table 44

Use of Agro-Chemicals for Minimizing the Alkalinity Hazards and Sustaining Crop Yield on Alkali Irrigated Soil – Kanpur

An experiment was conducted with Rice (NDR-359) and wheat (PBW-343) crops with twelve treatments replicated four times with RBD design at Crop Research Station, Nawabganj, Kanpur. Fertilizer were applied to both rice and wheat crop in the ratio of 120:60:60 (NPK) kg/ha. Before the start of experiment the soil were analysed and data showed that pH_s is 9.40, EC_e 3.21 dS/m, ESP 59.0, organic carbon 0.1 per cent, gypsum requirement is 13.0 t/ha and soil is loamy in texture.

The experiments results on grain yield of rice and wheat (Table 46) showed that application of gypsum @ 50, 100, and 150% GR were at par. Similarly, application of different doses of pyrite as well as press mud failed to show any significant difference in grain yield of rice and wheat.

The variation in average grain yield of rice (3.81, 3.72 and 3.50 t/ha) and wheat (3.41, 3.36 and 2.99 t/ha) due to the application of gypsum 50% GR or pyrite 50% GR or press mud @ 5 t/ha respectively were found to be non-significant.

Neutralization of RSC water through dissolution of gypsum in 15 cm gypsum bed increased yields of both rice and wheat significantly as compared to untreated irrigation water.

Table 46. Effect of various amendments on grain yield of rice and wheat (t/ha)

Treat-ments	Rice						Wheat					
	2004	2005	2006	2007	2008	Mean	2004-05	2005-06	2006-07	2007-08	2008-09	Mean
T_1	3.25	3.26	3.20	3.28	3.30	3.26	2.60	2.49	2.55	2.50	2.52	2.53
T_2	3.38	3.43	3.50	3.48	3.56	3.47	2.75	2.70	2.79	2.84	2.89	2.79
T_3	3.50	3.60	3.86	4.09	4.15	3.84	3.14	3.10	3.44	3.65	3.62	3.39
T_4	3.62	3.79	3.80	3.90	3.93	3.81	3.36	3.36	3.40	3.44	3.48	3.41
T_5	3.84	4.06	4.10	4.18	4.23	4.08	3.48	3.50	3.56	3.62	3.67	3.57
T_6	3.86	4.10	4.19	4.31	4.33	4.16	3.61	3.63	3.65	3.73	3.79	3.68
T_7	3.56	3.64	3.76	3.80	3.85	3.72	3.25	3.28	3.36	3.42	3.50	3.36
T_8	3.66	3.75	3.80	3.89	3.93	3.91	3.37	3.39	3.47	3.55	3.62	3.48
T_9	3.64	3.82	3.85	4.00	3.99	3.86	3.48	3.50	3.55	3.62	3.70	3.57
T_{10}	3.42	3.44	3.50	3.55	3.60	3.50	2.91	2.95	3.01	3.02	3.06	2.99
T_{11}	3.49	3.50	3.57	3.60	3.66	3.56	3.04	3.09	3.16	3.05	3.11	3.09
T_{12}	3.55	3.55	3.60	3.63	3.68	3.60	3.08	3.10	3.22	3.08	3.22	3.14
CD (5%)	0.24	0.28	0.31	0.25	0.18	-	0.27	0.31	0.29	0.24	0.19	-

T_1: All irrigation with RSC water; T_2 : All irrigation with BAW; T_3 : 2/3 Neutralization RSC, passing RSC water through 15 cm gypsum bed before irrigation; T_4:Gypsum application @ 50% GR (Soil application); T_5 :Gypsum application @ 100% GR (Soil application); T_6 : Gypsum application @ 150% GR (Soil application); T_7 :Pyrite @ 50% GR (Soil application); T_8 : Pyrite @ 100% GR (Soil application); T_9 :Pyrite @ 150% GR (Soil application); T_{10} :Press mud @ 5t/ha (Soil application); T_{11} :Press mud @ 10 t/ha (Soil application) and T_{12} :Press mud @ 15t/ha (Soil application)

The physico-chemical properties of soil (pH_s, EC_e and ESP) improved considerably under gypsum amended water, gypsum, pyrite and press mud treatments. There was remarkable change in soil pH_s (Table 47). The maximum soil pHs (9.33) was recorded in RSC treated plots followed by BAW treated (9.02). Dissolution of gypsum through gypsum bed reduced soil pH_s in the range 8.45-8.47. Among the three soil amendments tested, gypsum and pyrite found to be equally effective in reducing soil pH, followed by press mud. The value of EC_e (dS/m) was maximum (3.38-3.30) in RSC treated plots followed by BAW application, press mud, gypsum dissolution, pyrite and gypsum. The average ESP value in RSC treated plots remained highest (57.0-58.0) followed by BAW (50.0), press mud (29.0), gypsum dissolution (16.5), pyrite (15.1) and gypsum (13.9).

Change in ionic composition of RSC water

Crop irrigated with RSC water (8.85 to 8.96 meq/l) when passed through 15 cm gypsum bed showed reduction in RSC level and changes in ionic composition (Table 48). No significant changes in pH_{iw} values were observed but salt concentration (EC_{iw}) slightly increased and the increase was more at the time of last irrigation. A remarkable change in concentration of Ca and Mg were recorded. Initial average RSC value (8.90) reduced to 4.32 and 4.13 meq/l in *kharif* and *rabi* respectively.

It is concluded that there is no significant differences in yield of rice and wheat with higher doses of gypsum, pyrite and press mud. However, amendment increased the yield significantly over control (RSC-water), best being gypsum >pyrite >press-mud. Gypsum dissolution (15 cm gypsum bed) through irrigation found to be more beneficial than soil application.

Table 47. Effect of different treatments on chemical properties of soil (After 5 years)

Treat-ments	Depth (cm)	After rice			After wheat		
		pH_s	EC_e (dS/m)	ESP	pH_s	EC_e (dS/m)	ESP
T_1	00-20	9.33	3.28	57.0	9.33	3.30	58.0
	20-40	9.20	3.43	53.0	9.21	3.40	52.5
T_2	00-20	9.03	2.63	30.0	9.02	2.60	50.0
	20-40	8.85	2.55	41.0	8.81	2.98	42.0
T_3	00-20	8.47	2.15	18.0	8.45	2.10	16.5
	20-40	8.39	2.09	17.5	8.40	2.00	16.0
T_4	00-20	8.38	2.19	19.7	8.37	2.17	19.0
	20-40	8.30	2.22	16.3	8.29	2.25	16.0
T_5	00-20	8.13	1.99	14.9	8.13	1.95	14.5
	20-40	8.05	2.05	12.8	8.04	2.03	12.3
T_6	00-20	8.00	1.90	13.6	8.00	1.89	13.9
	20-40	7.86	2.10	11.5	7.89	2.06	11.5
T_7	00-20	8.40	2.23	22.6	8.36	2.20	22.0
	20-40	8.35	2.33	17.0	8.36	2.35	17.0
T_8	00-20	8.19	2.02	18.0	8.18	2.00	18.0
	20-40	8.10	2.08	13.0	8.16	1.36	17.0
T_9	00-20	8.04	1.25	15.5	8.01	1.93	15.1
	20-40	7.95	2.15	11.3	7.93	2.11	10.6
T_{10}	00-20	8.75	2.45	33.0	8.71	2.41	32.5
	20-40	8.88	2.56	30.5	8.75	2.52	30.0
T_{11}	00-20	8.46	2.30	29.9	8.45	2.25	29.0
	20-40	8.39	2.35	27.5	8.36	2.30	25.9
T_{12}	00-20	8.44	2.24	25.3	8.40	2.20	25.0
	20-40	8.35	2.30	23.6	8.33	2.24	23.0

Notations are same as given in Table 46

Table 48. Change in ionic composition of RSC irrigated water as a result of gypsum bed treatment (Av. 5 years)

Treatments	pH	EC (dS/m)	Anions (meq/l)				Cations (meq/l)		RSC (meq/l)
			CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na+K	
Untreated	8.2	1.2	NIL	10.7	0.8	0.7	1.8	10.0	8.9
Treated	7.9	1.5	NIL	10.4	1.1	3.9	6.2	9.5	4.2
BAW	7.5	0.7	NIL	4.1	3.3	0.1	6.4	1.0	NIL

Drip Irrigation to Vegetables in Alkali Soil using Amended Alkali Water - Tiruchirapalli

In order to compare the efficacy of ameliorated alkali water and drip irrigation to vegetables, an experiment was initiated during 2010. Treatments details are as below:

Main plot treatments: M_1-Drip irrigation with gypsum bed treated water; M_2-Drip irrigation with spent wash treated water; M_3 - Drip irrigation with untreated alkali water and M_4-Farmer's practice (furrow irrigation).
Sub-plot treatments comprise of G_1: Soil application of gypsum @ 50% GR and G_2: No gypsum.

The drip system was designed and laid out before sowing of vegetable crops viz., Okra and cluster bean in alkali soils of ADAC&RI farm with initial soil pH of 8.61 and EC 0.46 dS/m. The gypsum bed treatment structure (1000 litres) was fabricated with RCC rings and a mild steel rod stand. The inlet of the irrigation water is provided below the stand and the irrigation water was treated during its upward movement though the gypsum bed kept within a gunny bag over the stand. This treated water is being collected in a storage tank from which the water is pumped into drip system through the filter. Similarly, the spent wash was mixed with irrigation water in a ratio of 1:250 through the fertigation unit to treat the alkali water. The drip irrigation is being operated thrice in a week. The duration of water application in each drip irrigation treatment is estimated based on the average evaporation rate and the stage of the crop. The recommended quantities of N and K were given through the drip system as per the schedule. The full dose of P as super phosphate was applied as basal.

In the farmer's method, the seeds were sown in ridges and furrow system and fertilizer N and K was applied in three splits. The yield of the vegetable crops was recorded in staggered manner depending upon the maturity of the crop. The soil samples were collected after harvest of the crop and analysed for pH, EC and ESP.

The results of the field experiment showed that soil application of gypsum @ 50% GR significantly increased the yield of both Okra and cluster bean (Table 49). An increase of 12.7% in Okra and 22.1% in cluster bean was recorded due to soil application of gypsum @ 50% GR. Among the irrigation treatments, drip irrigation of spent wash treated water recorded the highest yield in Okra and drip irrigation of gypsum bed treated water recorded highest yield in cluster bean crop. The interaction effect showed that soil application of gypsum @ 50% GR along with drip irrigation of spent wash treated water recorded the highest Okra yield which was at par with soil application of gypsum @50% GR along with drip irrigation of gypsum bed treated water. In case of cluster bean, soil application of gypsum @ 50% GR along with drip irrigation of gypsum bed treated water recorded the highest yield which was at par with soil application of gypsum @ 50% GR along with drip irrigation of spent wash treated water. The lowest yield was recorded in the treatment without soil application of gypsum along with furrow irrigation of untreated alkali water both in okra and cluster bean.

Table 49. Effect of drip irrigation of ameliorated alkali water on yield of okra and cluster bean

Treatments	Okra			Cluster bean		
	S_1	S_2	Mean	S_1	S_2	Mean
M_1	11.26	10.42	10.84	6.72	5.38	6.05
M_2	11.98	10.9	11.44	6.21	5.02	5.62
M_3	10.2	8.8	9.50	5.41	4.76	5.09
M_4	8.89	7.42	8.16	4.89	3.86	4.38
Mean	10.58	9.39		5.81	4.76	
CD (5%)	M	S	MxS	SxM	M	S	MxS	SxM
	0.48	0.41	0.90	0.82	0.32	0.29	0.59	0.51

The results of the soil analysis revealed that soil application of gypsum @ 50% GR significantly reduced the pH of the post harvest soil below 8.5 from the initial level of 8.61 in both the crops. Similarly, the alkali water treatment (gypsum bed / spent wash) also significantly reduced the pH of the post harvest soil. With regards to interaction effect, furrow irrigation (farmer's practice) without gypsum recorded the highest soil pH (8.65 in Okra field and 8.68 in Cluster bean field) followed by drip irrigation of untreated alkali water without gypsum. Soil application of gypsum slightly increased the EC of post harvest soil. Similarly, spent wash treated water irrigation slightly increased the EC over other treatments. The interaction effect showed that drip irrigation with spent wash treated water with soil application of gypsum recorded maximum EC (0.52 dS/m in Okra field and

0.50 dS/m in cluster bean field). Drip irrigation with alkali water recorded the lowest soil EC (0.45 dS/m in Okra field and 0.46 dS/m in cluster bean field). Regarding ESP, furrow irrigation with untreated alkali water recorded the highest ESP followed by drip irrigation with untreated alkali water (Table 50). Soil application of gypsum @ 50% GR significantly reduced the ESP of post harvest soil to 14.25 and 14.38 respectively in Okra and cluster bean fields respectively from the initial level of 26.1. The interaction effect showed that furrow irrigation of untreated alkali water with no gypsum recorded the highest ESP, while soil application of gypsum with gypsum bed treated drip irrigation recorded the lowest ESP.

Table 50. Effect of drip irrigation using ameliorated alkali water on the ESP of soil

Treatments	Okra			Cluster bean		
	S1	S2	Mean	S1	S2	Mean
M_1	13.00	21.40	17.20	13.5	22	17.75
M_2	13.60	22.80	18.20	13.8	23.1	18.45
M_3	14.20	26.00	20.10	14.4	26.6	20.50
M_4	16.20	27.20	21.70	15.8	28	21.90
Mean	14.25	24.35		14.38	24.93	

CD (5%)	M	S	MxS	SxM	M	S	MxS	SxM
	0.86	0.72	1.20	1.31	0.70	0.81	1.12	1.18

Tolerence of Vegetables to Saline Water under Drip and Surface Methods of Irrigation - Bikaner

Studies were conducted to evaluate response of onion to saline water irrigation under drip and flood methods of irrigation. Maximum yield of onion was recorded under drip irrigation with water having EC_{iw} 3 dS/m with a significant decrease in yield with water having EC 6.0 dS/m. Drip method was superior with 24.1% higher yield as compared to flood irrigation. Bulb diameter and weight were also recorded higher under salinity of water having EC_{iw} 3.0 dS/m. At EC_{iw} 6.0 dS/m yield attributes of the crop decreased significantly (Table 51). The resulting EC_e of soil at harvest of onion was affected by salinity levels of irrigation water in 0-45 cm soil profile at 0, 15 and 30 cm lateral distances from the emitter (Table 52).

Table 51. Effect of saline water on onion under drip and flood methods of irrigation

Treatment	Yield (t/ha)		Bulb diameter (cm)		Weight of bulb (g)	
	08-09	09-10	08-09	09-10	08-09	09-10
Drip Irrigation						
BAW	46.3	25.63	6.25	6.10	106.3	85.2
EC_{iw} 3.0 dS/m	54.3	33.24	6.58	6.29	119.9	97.7
EC_{iw} 6.0 dS/m	38.6	16.22	5.94	5.73	100.6	78.7
Flood Irrigation						
BAW	40.1	19.43	5.90	5.88	91.1	75.3
EC_{iw} 3.0 dS/m	44.9	17.45	6.35	5.74	109.7	70.4
EC_{iw} 6.0 dS/m	30.3	9.96	5.46	4.93	79.7	62.2
SEm $\pm$	2.1	1.9	0.09	0.08	3.6	3.3
CD (5%)	6.6	5.9	0.31	0.27	11.3	10.4

BAW : EC_{iw} 0.25 dS/m

Table 52. Salinity (EC_e) build-up in the soil profile after harvest of onion

Distance from emitter (cm)	Soil depth (cm)	EC_{iw} (dS/m)					
		Drip			Flood		
		BAW	3.0	6.0	BAW	3.0	6.0
0	0-15	0.46	1.23	1.87	0.33	1.38	1.90
	15-30	0.48	1.26	1.96	0.41	1.36	2.08
	30-45	0.56	1.27	2.21	0.41	1.54	2.23
15	0-15	0.47	1.49	1.79	-	-	-
	15-30	0.46	1.53	2.03			
	30-45	0.46	1.68	2.30			
30	0-15	0.53	1.84	1.98	-	-	-
	15-30	0.49	1.84	2.17			
	30-45	0.50	1.89	2.39			

Performance of Micro (Drip) Irrigation System with Saline Water for Vegetable Crops - Bapatla

During 2008-09, an experiment was laid out with four levels of irrigation i.e., BAW of horizontal skimming well (<0.5 dS/m) and saline water of 2, 4, 6 dS/m (by mixing of fresh water and sea water of 35 dS/m or more) to know the response of vegetable crops viz., tomato, okra and brinjal under drip irrigation.

The mean yield of okra showed that with BAW highest yield of 2.82 t/ha was obtained followed by 2.60 t/ha, 1.01 t/ha , 0.51 t/ha with 2, 4 and 6 dS/m water treatments, which showed 7.71, 64.01 and 82.04 per cent reduction in the yield respectively.

The mean yield of tomato showed that with BAW highest yield of 7.61 t/ha could be obtained followed by 7.45 t/ha, 4.95 t/ha , 3.11 t/ha with 2, 4 and 6 dS/m water treatments, which recorded 2.06, 34.91 and 59.12 per cent reduction in yield respectively.

During 2009-10 the mean yield of tomato was recorded the highest with BAW at 14.97 t/ha followed by 14.38 t/ha, 10.78 t/ha , 7.88 t/ha in drip irrigation with 2, 4 and 6 dS/m water treatments, which resulted in 3.97, 27.99 and 47.33 per cent reduction in yield respectively. The threshold salinity levels for 90, 75 and 50 per cent yield of tomato are 2.4, 4.0 and 6.1 dS/m respectively (Table 53).

The mean yield of okra yield reduced by 7.49, 44.85 and 67.41 per cent with 2, 4 and 6 EC_{iw} as compared to BAW. The threshold salinity levels for 90%, 75% and 50% yield of okra are 1.65, 2.9 and 4.7 dS/m respectively (Table 53).

The mean yield of brinjal showed that fresh water treatment (0.5 dS/m) recorded the highest yield of 5.02 t/ha followed by 4.56 t/ha, 3.50 t/ha, 1.25 t/ha in drip with 2, 4 and 6 dS/m water treatments, which showed 9.1, 31 and 76 per cent reduction in the yield respectively. The threshold salinity levels for 90, 75 and 50 per cent yield of brinjal are 2.36, 3.6 and 5.0 dS/m respectively (Table 53).

Soil samples were collected in the experimental fields at initial stage, middle and after harvest. The mean salinity build-up in 0 – 15 cm depth from 0.22 dS/m to 0.58 dS/m after harvest in fresh water irrigation treatment followed by 2, 4 and 6 EC treatments with 0.52 – 1.27 dS/m, 0.34 – 2.01 dS/m and 0.46 – 2.40 dS/m respectively. The corresponding values of EC for 15- 30 cm depth were 0.14 – 1.42 dS/m, 0.07 – 0.39 dS/m, 0.17 – 0.44 dS/m and 0.09 – 0.85 dS/m in fresh water, 2, 4 and 6 EC irrigation treatments respectively (Table 53).

Data analysis

To develop a relationship between salinity and yield, the salinity levels (Z) versus mean yields (Y) were plotted and best fit equations were developed for all the experimental treatments (Fig. 15a, b and c). The best fit curves of polynomial type in all cases are presented below:

Tomato $Y = - 0.1135 x^2 - 0.6185x + 15.533$
Okra $Y = - 0.0196 x^2 - 0.3662x + 4.0633$
Brinjal $Y = - 0.1138 x^2 - 0.0662x + 4.9765$

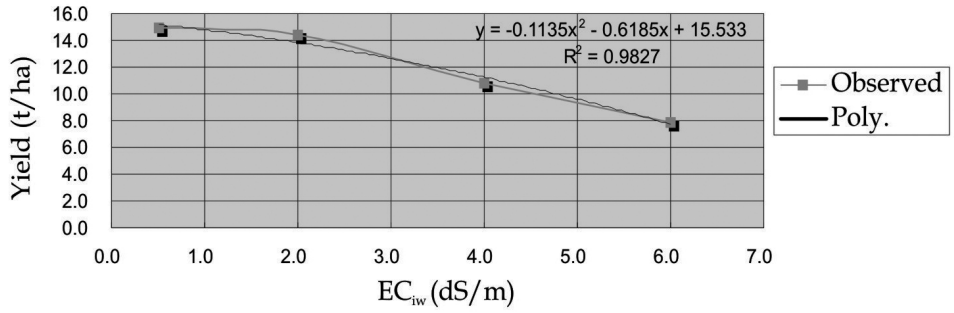


Fig. 15a. Irrigation water salinity Vs yield of tomato under drip

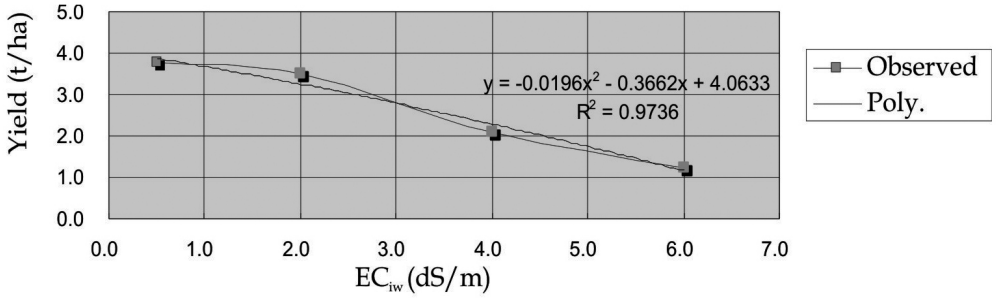


Fig. 15b. Irrigation water salinity Vs yield of okra under drip

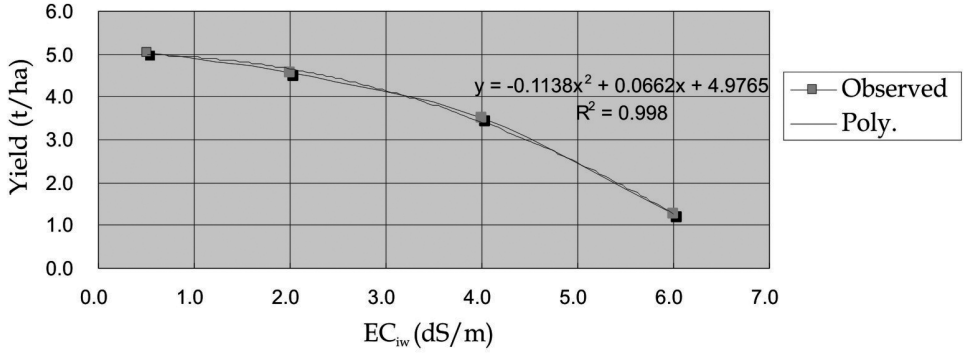


Fig. 15c. Irrigation water salinity Vs yield of brinjal under drip

Table 53. Crop-wise EC_{iw} levels for 90, 75 and 50 per cent yield levels

Parameters	Yield levels		
	90%	75%	50%
	Tomato		
Achievable yield (t/ha)	13.46	11.24	7.54
Salinity of irrigation water (dS/m)	2.40	4.00	6.10
	Okra		
Achievable yield (t/ha)	3.41	2.84	1.91
Salinity of irrigation water (dS/m)	1.65	2.90	4.70
	Brinjal		
Achievable yield (t/ha)	4.50	3.77	2.51
Salinity of irrigation water (dS/m)	2.35	3.56	4.96

Performance of Pearl millet-Wheat Crop Rotation Irrigated with Sodic Water through Sprinkler System under different Depths of Irrigation- Hisar

The study on use of sodic water through sprinkler system in pearl millet-wheat crop rotation with different doses of gypsum as an amendment was conducted at Regional Research Station, CCS HAU at Bawal during *rabi* 2002 to *rabi* 2009. Three irrigation depths (4, 5, 6 cm) in main plots and four gypsum treatments (0, 50, 75 and 100 per cent neutralization of RSC represented as G_0, G_1, G_2, G_3 and G_4, respectively) in sub plots were replicated thrice in a split plot design. The plot size was 10 m x 4 m. The crop was irrigated with sodic water of average RSC 12.0 meq/l and SAR 19.3 $(mmol/l)^{1/2}$ (Table 54). The water is bicarbonate type with HCO_3^- content being 14.0 meq/l. The requisite amount of gypsum in various treatments was applied in a single dose before sowing of the crop and mixed well in the upper 10 cm soil.

Table 54. Ionic composition and quality parameters of irrigation water

Ion/parameter	Values
CO_3 (meq/l)	nil
HCO_3 (meq/l)	14.0
Ca (meq/l)	0.4
Mg (meq/l)	1.6
Cl (meq/l)	5.6
EC_{iw} (dS/m)	1.93
RSC_{iw} (meq/l)	12.0
SAR_{iw} $(mmol/l)^{1/2}$	19.3

The important physico-chemical properties of the soil are given in Table 55. The texture of the soil of the experimental site is loamy sand with 17-21 per cent silt + clay content and remaining (79-83 per cent) sand. The soil is non-calcareous and non-gypsiferrous with low organic carbon (0.06-0.13 per cent) having cation exchange capacity of 3.9 cmol (P^+)/kg soil. The pH of the soil profile increased from surface to 45 cm and then remained almost at the same level up to 120 cm depth (Table 56). The soil of the experimental area up to a depth of 150 cm was non-saline and it varied from 0.38-0.53 dS/m and showed an increasing trend with depth.

Table 55. Some physico-chemical characteristics of experimental soil

Soil properties	Soil depth (cm)	
	0-15	15-30
Silt + clay (%)	17	21
Sand (%)	83	79
Textural class	Loamy sand	Loamy sand
pH (1:2)	9.25	9.30
$CaCO_3$ (%)	Traces	Traces
CEC (Cmol (P^+/kg)	3.9	4.0
Organic carbon (%)	0.13	0.06

Table 56. pH and EC_2 of soil profile before start of experiment (2006)

Soil depth (cm)	pH	EC_2 (dS/m)
0-15	9.35	0.38
15-30	9.52	0.41
30-45	9.55	0.39
45-60	9.42	0.39
60-90	9.38	0.48
90-120	9.41	0.53
Mean	9.44	0.43

During 2008-09, the grain and straw yield of pearl millet increased significantly with increase in depth of irrigation water and gypsum application. The mean grain yield of pearl millet increased by 21.7, 36.5 and 41.7 per cent with G_{50}, G_{75} and G_{100} neutralization of RSC (12.0 meq/l) over control G_0 through sprinkler system, respectively (Table 57). The grain yields in 5 cm and 6 cm irrigation depth increased by 13.1 and 18.5 per cent, respectively as compared to 4 cm water application. Similar trend of increase was observed in the straw yield of pearl millet also. The mean straw yield of pearl millet increased by 23.0, 45.1 and 49.3 per cent with G_{50}, G_{75} and G_{100} neutralization of RSC (12.0 meq/l) over control G_0. The straw yields in 5 cm and 6 cm irrigation depth increased by 7.8 and 15.2 per cent, respectively as compared to 4 cm water application.

Table 57. Grain yield (t/ha) of pearl millet irrigated with sodic water using sprinkler irrigation

Gypsum levels	Depth of irrigation (cm)			Mean
	4	5	6	
G_0	1.04	1.18	1.24	1.15
G_{50}	1.23	1.44	1.52	1.40
G_{75}	1.44	1.60	1.68	1.57
G_{100}	1.50	1.66	1.73	1.63
Mean	1.30	1.47	1.54	
CD (5%)	Gypsum level (G): 0.11; Depth of irrigation (D): 0.10; G x D: NS			

G_0: 0; G_{50} : 50; G_{75} : 75 and G_{100} : 100% neutralization of RSC water

The pH of the soil decreased gradually and continuously with the addition of gypsum. The highest pH of 9.01 was recorded in G_o treatment receiving 6 cm irrigation whereas the lowest pH was observed in G_{100} (100 per cent neutralization of RSC) treatment with 4 cm of irrigation.

Similarly, the grain yield of wheat during 2008-09 significantly increased with increasing levels of gypsum application and depth of irrigation (Table 58). The mean grain yield increased by 22.9, 33.6 and 37.9 per cent in G_{50}, G_{75} and G_{100} neutralization of RSC (12.0 me/l) over control, respectively. The grain yield also increased significantly with the increase in depth of irrigation from 4 cm to 6 cm in

both crops. The overall increase in grain yield of wheat in 5 and 6 cm depth of irrigation was 7.4 and 10.8 per cent respectively as compared to 4 cm depth.

Table 58. Grain yield (t/ha) of wheat irrigated with sodic water using sprinkler irrigation

Gypsum levels	Depth of irrigation (cm)			Mean
	4	5	6	
G_0	2.86	3.03	3.14	3.01
G_{50}	3.47	3.76	3.87	3.70
G_{75}	3.77	4.08	4.22	4.02
G_{100}	3.92	4.20	4.33	4.15
Mean	3.51	3.77	3.89	
CD (5%)	Gypsum level (G): 0.19; Depth of irrigation (D): 0.15; G x D: NS			

The pH values of the soil at the wheat harvest are given in Table 59. The pH of the soil decreased gradually and continuously with the addition of gypsum. The highest pH of 9.89 was recorded in G_o treatment receiving 6 cm irrigation whereas the lowest pH was observed in G_{100} (100 per cent neutralization of RSC) treatment which received 4 cm irrigation.

Table 59. Effect of gypsum level on pH of soil after the harvest of the wheat

Gypsum levels	Depth of irrigation (cm)		
	4	5	6
G_0	9.48	9.66	9.89
G_{50}	9.35	9.48	9.68
G_{75}	9.22	9.25	9.35
G_{100}	9.05	9.12	9.18

Crop Water/salinity Production Functions for different Crops using Sprinkler Irrigation- Agra

The experiment was conducted during 2008-09 to develop crop water production function of cluster bean-mustard crop rotation by creating salinity/alkalinity gradients though sprinkler line source. The plot size was 12m x 12m with three plots in a row. The treatments included three salinity levels (BAW, EC_{iw} 9.5 dS/m and mixture) and three RSC levels (BAW, RSC 9.5 meq/l and mixture). The sprinklers were set at 6 m distances in row. The data revealed that water depth decreased with increased distance from sprinkler line incase of saline/alkali and BAW alone. In saline and BAW alone, the depth of irrigation was recorded from 0.74 to 3.64 cm every irrigation (Table 60, 61).

In case of mixing, the irrigation depth was recorded from 3.38 to 5.35 cm every irrigation. The salinity or RSC level of irrigation water remained almost same irrespective of depth in the area where single saline/alkali or BAW (EC_{iw} 3.6 dS/m and RSC_{iw} nil) were applied. In case of mixing, the EC_{iw} and RSC_{iw} varied with distance. In case of saline and BAW, EC_{iw} of mixed water ranged from 4.7 to 8.4 dS/m, and RSC and BAW mixing plots RSC_{iw} ranged from 1.8 to 7.7 meq/l. The yield data of both the sets of experiment indicated that the mustard yield was affected by salinity/RSC gradients. In single sprinkler line, the grain yield significantly decreased with decreasing irrigation depth in saline/sodic and BAW plots (Table 60).

Mustard yield was affected by water and salinity/RSC gradients. The yield increased with the increase in depth of irrigation water away from sprinkler lines and increased by 38.0 per cent with saline (EC_{iw} 10 dS/m) water depth from 0.74 to 2.70 cm (one nozzle plot) per irrigation, whereas in two and three nozzle plots, the increase in yield was 26.9 and 37.4 per cent with water depth of 0.8 to 3.44 and 0.81 to 3.64 cm per irrigation, respectively. In mixing (BAW + EC_{iw} 10 dS/m) plots, the irrigation depth varied marginally. However, EC_{iw} ranged in one, two and three nozzle from 7.4 to 4.7, 7.9 to 4.8 and 8.0 to 4.9 dS/m and yield declined by 11.1, 11.8 and 11.3 per cent, respectively.

In RSC block also, average yield increased with increase in depth of water away from sprinkler lines and increased by 20.6 per cent with water depth varying from 0.74 to 2.70 cm (one nozzle plot) per irrigation, whereas in two and three nozzle plots, the increase in yield was 21.7 and 29.7 per cent with depth 0.80 to 3.44 and 0.81 to 3.64 cm per irrigation, respectively. In mixing (BAW + RSC_{iw} 10) plots the RSC_{iw} ranged from 7.1 to 1.8, 7.2 to 1.9 and 7.2 to 2.0 (meq/l) in one, two and three nozzle and yield declined by 8.4, 8.4 and 7.8 per cent, respectively.

In BAW (EC_{iw} 3.6 dS/m, RSC nil) plot, the average yield increased by 29.8 per cent with increase in water depth from 0.74 to 2.70 cm (one nozzle plot) per irrigation whereas, in two and three nozzle plots, the average yield increased by 25.1 and 34.7 per cent with depth varying from 0.80 to 3.44 and 0.81 to 3.64 cm per irrigation, respectively.

Table 60. Effect of gradient of water and salinity on yield, EC_e and WUE of mustard

Space (cm)	Depth of each irrigation (cm)	EC_{iw} (dS/m)	Cluster bean grain yield (t/ha)		Mustard grain yield (t/ha)			WUE# in mustard (kg/ha-cm)	EC_e* # (dS/m) 0-30 cm
			2008**	2009	2008-09	2009-10	Av.		
EC_{iw} 10 (dS/m)									
One nozzle									
4	2.70	9.5	10.3	0.74	2.40	1.65	2.02	445.9	9.0
8	1.85	,,	10.1	0.92	2.30	1.51	1.90	516.9	8.4
12	0.74	,,	6.1	0.89	1.28	1.28	1.28	6090	4.2
Two nozzle									
4	3.44	,,	7.8	0.60	2.13	1.53	1.83	378.4	9.8
8	1.87	,,	9.7	0.51	2.10	1.51	1.80	476.4	8.4
12	0.80	,,	9.0	1.00	1.33	1.20	1.26	749.6	4.6
Three nozzle									
4	3.64	,,	5.6	0.52	2.33	1.56	1.94	386.1	10.2
8	1.96	,,	6.3	0.43	2.15	1.80	1.97	548.9	9.1
12	0.81	,,	6.4	0.83	1.40	1.27	1.33	568.6	5.0
Mixing (EC_{iw} 10 + BAW)									
One nozzle									
4	3.55	7.4	7.6	0.44	2.20	1.40	1.80	359.4	10.2
8	3.55	6.1	7.0	0.65	2.42	1.66	2.04	394.1	9.6
12	3.54	4.7	4.9	0.68	2.64	1.66	2.15	398.6	5.9
Two nozzle									
4	4.58	7.9	8.2	0.53	2.12	1.37	1.74	287.3	10.1
8	5.07	6.3	8.5	0.67	2.29	1.38	1.83	284.6	8.1
12	4.46	4.8	7.8	0.72	2.51	1.68	2.09	348.8	5.9
Three nozzle									
4	4.60	8.0	7.1	0.54	2.12	1.33	1.72	304.3	10.5
8	4.84	6.4	8.6	0.67	2.31	1.46	1.88	282.6	8.4
12	4.60	4.9	8.2	0.68	2.64	1.72	2.18	319.7	6.7
BAW									
One nozzle									
4	2.70	3.6	9.90	0.74	2.41	1.71	2.06	545.2	3.6
8	1.85	,,	9.80	0.97	2.15	1.59	1.87	499.2	3.4
12	0.74	,,	8.30	1.12	1.58	1.35	1.47	600.0	3.2
Two nozzle									
4	3.44	,,	9.20	0.78	2.27	1.89	2.08	401.9	3.7
8	1.87	,,	9.90	0.87	2.28	1.64	1.96	569.6	3.4
12	0.80	,,	9.80	1.01	1.65	1.41	1.53	706.1	3.1
Three nozzle									
4	3.64	,,	9.90	0.99	2.44	1.78	2.11	412.6	3.8
8	1.96	,,	8.90	0.76	2.11	1.56	1.83	500.9	3.4
12	0.81	,,	9.60	0.83	1.58	1.40	1.49	663.4	3.0

**After harvest of mustard (0-30 cm depth); ** Fodder yield; #Values are average of two years*

Table 61. Effect of gradients of water and RSC on yield, ESP and WUE of mustard

Space (cm)	Depth of each irrigation (cm)	RSC_{iw} (meq/l)	Cluster bean grain yield (t/ha)		Mustard grain yield (t/ha)			WUE# in mustard (kg/ha-cm)	ESP* # (meq/l) 0-30 cm
			2008**	2009	2008-09	2009-10	Av.		
					RSC_{iw} 10 (meq/l)				
One nozzle									
4	2.70	9.5	3.15	0.71	2.45	1.62	2.03	441.0	23.2
8	1.85	,,	4.15	0.96	2.39	1.70	2.04	583.0	20.8
12	0.74	,,	3.46	1.09	1.53	1.45	1.49	649.2	12.4
Two nozzle									
4	3.44	,,	2.42	0.68	2.35	1.60	1.98	381.2	24.9
8	1.87	,,	2.85	0.88	2.22	1.60	1.91	526.0	23.6
12	0.80	,,	6.29	1.17	1.60	1.22	1.41	611.6	15.4
Three nozzle									
4	3.64	,,	3.48	0.62	2.34	1.51	1.92	388.9	25.2
8	1.96	,,	2.73	0.68	2.16	1.41	1.78	511.1	23.2
12	0.81	,,	2.75	0.90	1.58	1.20	1.39	669.6	17.1
					Mixing (RSC_{iw} 10 + BAW)				
One nozzle									
4	3.55	7.4	2.96	0.53	2.50	1.36	1.93	442.2	19.8
8	3.55	6.1	3.88	0.74	2.32	1.40	1.86	349.9	16.0
12	3.54	4.7	5.65	0.87	2.05	1.70	1.87	369.5	13.0
Two nozzle									
4	4.58	7.9	4.21	0.60	2.44	1.35	1.89	261.5	19.1
8	5.07	6.3	5.75	0.75	2.18	1.42	1.80	279.6	18.2
12	4.46	4.8	8.54	0.91	1.89	1.51	1.70	337.2	12.0
Three nozzle									
4	4.60	8.0	2.79	0.67	2.36	1.39	1.87	316.0	18.3
8	4.84	6.4	6.04	0.63	2.16	1.39	1.77	292.0	15.2
12	4.60	4.9	6.88	0.68	1.97	1.48	1.72	290.0	12.9
					Best Available Water				
One nozzle									
4	2.70	Nil	9.90	0.74	2.41	1.71	2.06	545.2	10.9
8	1.85	,,	9.80	0.97	2.15	1.59	1.87	499.2	9.6
12	0.74	,,	8.30	1.12	1.58	1.35	1.47	600.0	8.3
Two nozzle									
4	3.44	,,	9.20	0.78	2.27	1.89	2.08	401.9	10.8
8	1.87	,,	9.90	0.87	2.28	1.64	1.96	569.6	10.0
12	0.80	,,	9.80	1.01	1.65	1.41	1.53	706.1	8.0
Three nozzle									
4	3.64	,,	9.90	0.99	2.44	1.78	2.11	412.6	11.6
8	1.96	,,	8.90	0.76	2.11	1.56	1.83	500.9	9.9
12	0.81	,,	9.60	0.83	1.58	1.40	1.49	663.4	8.7

**After harvest of mustard (0-30 cm depth); ** Grain yield; #Values are average of two years*

Status of Fluoride in Underground Irrigation Water of Ladnu Tehsil in Nagaur District and its Effect on Soil Properties and Crops - Bikaner

Fluoride occurs in ground waters of many districts of Rajasthan. In Nagaur district fluoride content ranges between 0-25 mg/l. About 20% water samples have F content >5 mg/l. From drinking point of view, critical limit of F being 1.5 mg/l, 62% water samples in Nagaur district are reported to have F above the permissible limit. Since the information on the effects of Fluoride in irrigation water on soil

properties and plant growth is very meager, therefore, an experiment being conducted to know the harmful effects of F of underground irrigation water on soil properties and different crops.

Ground water samples from 52 tube wells of 29 villages of Ladnu tehsil of Nagaur district were collected during 2007. Surface soil samples were also collected from the fields irrigated with corresponding waters. These water and soil samples were analyzed for their chemical characteristics and fluoride contents and presented in Table 62 and 63.

The water table in Ladnu tehsil varied from 53.3 to 200 m. EC and pH of water samples ranged from 1.02 to 7.12 dS/m and 7.2 to 8.5, respectively. The concentration of flouride varied from 1.0 to 8.8 mg/l (Table 62). EC_2 , pH_2 and fluoride content of soil samples ranged between 0.18 to 2.93 dS/m, 8.0 to 8.7 and 0.47 to 3.8 mg/l, respectively (Table 63).

Per cent distribution of fluoride content in water samples w.r.t pH and EC is presented in Table 64. Only 17.2 per cent water samples are safe for drinking purpose (1.5 mg/l) whereas, 3.8, 32.8, 35.5 and 9.6 per cent water samples are in the range of 1.5-2.5, 2.5-5.0, 5.0-7.5 and >7.5 mg/l, respectively. About 25 and 75 per cent water samples showed pH in the range of 7.5-8.0 and 8.0-8.5, respectively. In respect of salinity about 19.2, 44.3, 24.9 and 11.5 per cent water samples had EC <2.0, 2.0-4.0, 4.0-6.0 and >6.0 dS/m, respectively.

Table 62. Chemical characteristics of ground water of Ladnu tehsil in Nagaur district

S. No.	Name of village	Water table depth (m)	pH	EC (dS/m)	Fluoride (mg/l)	Year of start
1.	Khamiad	53.3	7.8	6.24	7.8	1998
2.	Dhulia	56.7	8.1	6.72	5.6	2000
3.	Ratau	66.7	8.2	6.48	1.3	1997
4.	Ratau	70.0	8.3	4.43	1.4	2000
5.	Ratau	70.0	8.0	5.37	1.6	2000
6.	Sikarali	73.3	8.1	6.95	8.7	1998
7.	Malgoan	133.3	8.2	4.55	7.5	2003
8.	Malgoan	121.3	7.8	5.52	8.8	1999
9.	Sandas	86.7	8.1	7.12	7.8	2000
10.	Sandas	66.7	8.1	6.52	5.1	2005
11.	Bhakaron ki dhani	70.0	8.1	4.98	4.2	1997
12.	Bhakaron ki dhani	70.0	8.2	4.95	4.4	2000
13.	Bidasaron ki dhani	75.0	8.0	3.23	4.4	2001
14.	Lokat	133.3	8.2	5.29	5.4	2003
15.	Genana	100.0	8.3	1.82	1.3	1996
16.	Genana	100.0	8.3	1.76	1.2	1997
17.	Baldoo	100.0	8.5	1.75	5.2	1994
18.	Baldoo	86.7	8.3	2.45	4.8	1993
19.	Khokari	116.7	8.2	2.08	6.6	2005
20.	Khokari	93.3	8.0	2.41	5.4	2003
21.	Nimbi Jodha	113.3	7.9	2.62	5.7	1998
22.	Nimbi Jodha	116.7	8.2	2.30	5.9	2003
23.	Beron ki dhani	110.0	7.9	2.92	3.2	1997
24.	Beron ki dhani	110.0	8.1	2.53	3.8	1993
25.	Jhardia	120.0	7.9	2.16	3.0	1998
26.	Jhardia	83.3	7.9	4.34	4.5	2000
27.	Bharnawa	73.3	7.7	5.80	6.0	2001

S. No.	Name of village	Water table depth (m)	pH	EC (dS/m)	Fluoride (mg/l)	Year of start
28.	Bharnawa	68.7	8.0	5.48	4.0	2000
29.	Manoo	200.0	7.9	3.60	1.6	2006
30.	Chandrai	150.0	7.9	4.03	5.8	2001
31.	Chandrai	150.0	8.1	1.95	3.5	2003
32.	Lukas	166.7	7.8	1.80	3.0	2003
33.	Lukas	125.0	7.9	3.02	3.2	2001
34.	Audit	126.7	8.1	1.49	1.2	1994
35.	Audit	66.7	8.1	2.31	1.4	1988
36.	Heerawati	133.3	8.1	1.02	1.0	2001
37.	Heerawati	150.0	8.1	1.40	1.3	1995
38.	Sunari	133.3	8.4	2.07	2.5	2005
39.	Sunari	150.0	8.1	4.24	4.4	1997
40.	Natas	121.7	8.2	2.60	6.7	1988
41.	Natas	120.0	8.1	3.17	6.3	2002
42.	Dujar	122.3	8.1	3.15	6.8	2001
43.	Dujar	133.3	8.2	1.97	8.1	2001
44.	Bakolia	150.0	8.0	2.62	5.7	2000
45.	Bakolia	106.7	8.2	2.76	7.1	2001
46.	Baded	100.0	8.2	2.28	4.3	1993
47.	Baded	133.3	8.1	2.50	3.7	1995
48.	Bhaid	150.0	8.1	1.60	4.1	1995
49.	Bhaid	108.3	8.0	2.18	5.0	2003
50.	Koyal	150.0	8.0	2.16	5.6	1998
51.	Koyal	150.0	7.9	2.08	5.2	1997
52.	Titari	60.0	7.2	5.10	1.7	2000
	Minimum	53.3	7.20	1.02	1.0	
	Maximum	200.0	8.50	7.12	8.8	

Table 63. Chemical characteristics of soil irrigated with tube well water of Ladnu tehsil

S.No.	Name of village	pH	EC_{iw} (dS/m)	Fluoride (mg/l)
1	Khamiad	8.5	2.93	2.22
2	Dhulia	8.4	1.50	1.87
3	Ratau	8.6	1.69	1.67
4	Ratau	8.5	0.44	1.74
5	Ratau	8.6	0.53	1.80
6	Sikarali	8.4	0.79	1.65
7	Malgoan	8.3	0.65	1.80
8	Malgoan	8.5	0.44	1.58
9	Sandas	8.2	1.49	1.78
10	Sandas	8.4	1.02	1.31
11	Bhakaron ki dhani	8.3	0.61	1.58
12	Bhakaron ki dhani	8.1	0.52	1.68
13	Bidasaron ki dhani	8.3	0.37	1.28
14	Lokat	8.1	1.38	1.23

S.No.	Name of village	pH	EC_{iw} (dS/m)	Fluoride (mg/l)
15	Genana	8.3	0.49	1.23
16	Genana	8.4	0.32	1.58
17	Baldoo	8.6	0.36	1.50
18	Baldoo	8.4	0.49	1.83
19	Khokari	8.3	0.47	1.82
20	Khokari	8.5	0.34	2.67
21	Nimbi Jodha	8.1	0.35	1.52
22	Nimbi Jodha	8.4	0.38	1.77
23	Beron ki dhani	8.5	0.44	1.53
24	Beron ki dhani	8.4	0.44	1.72
25	Jhardia	8.7	0.34	1.76
26	Jhardia	8.1	0.88	2.05
27	Bharnawa	8.1	0.55	2.53
28	Bharnawa	8.2	0.45	0.48
29	Manoo	8.1	0.26	0.70
30	Chandrai	8.1	0.63	0.55
31	Chandrai	8.2	0.28	0.58
32	Lukas	8.0	0.22	0.81
33	Lukas	8.2	0.45	0.58
34	Audit	8.1	0.20	0.49
35	Audit	8.2	0.21	0.63
36	Heerawati	8.2	0.18	0.7
37	Heerawati	8.3	0.22	0.52
38	Sunari	8.6	0.30	0.51
39	Sunari	8.2	0.55	0.54
40	Natas	8.4	0.41	3.4
41	Natas	8.3	0.41	3.32
42	Dujar	8.2	0.35	0.47
43	Dujar	8.5	0.75	3.8
44	Bakolia	8.2	0.48	0.53
45	Bakolia	8.4	0.37	2.34
46	Baded	8.4	1.26	0.54
47	Baded	8.2	0.44	0.55
48	Bhaid	8.2	0.49	0.54
49	Bhaid	8.1	0.30	0.51
50	Koyal	8.3	0.49	0.65
51	Koyal	8.2	0.35	1.05
52	Titari	8.6	1.08	1.57
	Maximum	8.0	0.18	0.47
	Minimum	8.7	2.93	3.80

Correlation between water and soil characteristics was also worked out. Correlation between EC_{iw} and EC_{soil} & F_w and F_{soil} were found positive and significant, the corresponding "r" values were 0.647** and 0.433**, respectively. Correlation between pH_{soil} and F_{soil} was positive and significant (r= + 0.403**) and correlation between EC_{soil} and F_{soil} was positive but non significant (r= + 0.230).

Table 64. Per cent distribution of fluoride (F) content in water samples in relation to pH and EC

Chemical characteristics	Fluoride content (mg/l)						
	<1.5	1.5-2.5	2.5-5.0	5.0-7.5	>7.5	Total	"r"
pH							
7.5-8.0	3.8	-	9.7	8.6	1.9	25.0	
8.0-8.5	13.5	3.8	23.1	26.9	7.7	75.0	+0.017
EC (dS/ m)							
<2.0	9.6	-	5.8	1.9	1.9	19.2	
2.0-4.0	1.9	1.9	17.4	23.1	-	44.3	+ 0.307*
4.0-6.0	3.8	1.9	9.6	7.7	1.9	24.9	
>6.0	1.9	-	-	3.8	5.8	11.5	
Total	17.2	3.8	32.8	35.5	9.6		

Strategies for Conjunctive Use of Saline and Canal Water in Cotton-Wheat Crop Rotation - Hisar

A field experiment was conducted to evaluate the effect of conjunctive use of canal/saline water on growth, yield of cotton-wheat and pearl millet-mustard crop rotations and on soil salinity build-up at CCSHAU, Hisar farm. The experiments were conducted in micro-plots of size 4.5 m x 3.0 m. Treatments were replicated thrice in the randomized block design. Each micro-plot was separated by buffer of 1 meter width from all sides to arrest the horizontal movement of water and salts from the adjoining plot. Recommended cultural practices and fertilizer doses were applied in raising the crops. Uniform fertilizer applications were made in all the treatments using urea, DAP and zinc sulphate. Growth parameters and yield attributes for each treatment were recorded. The soil samples were collected from 0-15, 15-30, 30-60 and 60-90 cm layers before sowing and after the harvesting of each crop from all replications to determine the salt build up. The electrical conductivity of canal water and tube well/saline water were 0.4 and 7.5- 8.0 dS/m respectively.

In cotton during 2008-09, the highest seed cotton yield of 1.77 t/ha was recorded in canal irrigation followed by 2 canal (C) : 1 saline (S) cyclic irrigation (Table 65). The lowest yield (1.36 t/ha) was obtained under saline irrigated plots which indicated 23.7 per cent reduction in seed cotton yield as compared to canal treatment. The plant height and bolls/plant also varied significantly in saline irrigation as compared to canal (control). The plant height varied from 131.00 to 161.23 cm and a reduction of 16.94 per cent was observed in number of bolls/plant in saline treatment as compared to canal. However, differences among various treatments in respect of bolls weight were non-significant. The maximum boll weight of 3.02 gm was recorded in canal treatment.

Similarly, during 2009-10, irrigation with saline water decreased the seed cotton yield significantly. The data revealed that the highest seed cotton yield of 2.88 t/ha was recorded in 2 canal (C) : 1 saline (S) followed by 1 canal (C) : 1 saline (S) cyclic irrigation (Table 65). The lowest yield (1.75 t/ha) was obtained under all saline irrigated plot. A reduction of 36 and 31 per cent were observed in all saline and 2S : 1C irrigations, respectively, as compared with canal. The differences among C, 2C : 1S and 1C : 1S were, however, non-significant. The plant height and bolls/plant also varied significantly in saline irrigation as compared to canal (control). The plant height varied from 148.88 to 181.22 cm and a reduction of 20.0 per cent was observed in number of bolls/plant in saline treatment as compared to canal (Table 65). However, differences among various treatments in respect of bolls weight were non-significant. The maximum boll weight of 3.16 gm was recorded in canal treatment.

The water use by cotton crop under different treatments, depletion from soil, effective rainfall and post sown irrigations are presented in Table 66. The moisture use from soil profile was relatively more under canal water or canal water followed by saline water treatments. The maximum of 41.3 cm and minimum of 40.1 cm of total water was used in 2C:1S and saline water treatment, respectively.

Water productivity (WP) of irrigation water which was 146.0 kg/cm under saline water treatment increased to 239.7 kg/cm under 2C:1S treatment. WP of total water also increased from 43.7 under saline water irrigation to 69.6 under 2C:1S irrigation water treatment.

Table 65. Growth, yield attributes and yield of cotton as affected by different treatments

Treatments	Plant height (cm)		Bolls/plant		Boll weight (gm)		Seed cotton yield (t/ha)	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
C	161.3	181.2	21.67	25	3.02	3.16	1.77	2.74
1C: 1S	145.0	169.2	19.33	22	2.92	3.05	1.67	2.79
1S: 1C	141.0	167.6	19.00	21	2.83	2.92	1.54	2.47
2C:1S	151.0	179.3	21.33	26	3.00	3.13	1.70	2.88
2S:1C	137.7	154.0	18.67	19	2.85	2.92	1.46	1.90
PSS: RTC	146.0	174.3	19.00	21	2.85	3.00	1.56	2.53
1C: RTS	135.0	169.6	19.00	22	2.82	3.05	1.52	2.37
S	131.0	148.9	18.00	20	2.72	2.77	1.36	1.75
CD (5%)	13.8	12.1	1.36	3.50	NS	0.20	0.21	0.33

C: Canal water; S: Saline water; RTS : Rest of irrigation with saline water (dS/m); PSS : Pre-sowing with saline and RTC : Rest with canal water

Table 66. Water use by cotton under different treatments

Treatments	Amount of water use (cm)					Water productivity (kg/cm)	
	Soil moisture depletion	Effective rainfall	Post sown irrigation		Total		
			Canal	Saline		Irrigation water	Total water
C	8.2	20.7	12.0	0.0	40.9	228.3	67.0
1C : 1S	8.4	20.7	6.0	6.0	41.1	232.4	67.9
1S : 1C	7.8	20.7	6.0	6.0	40.5	205.7	60.9
2C : 1S	8.5	20.7	0.0	12.0	41.3	239.7	69.6
2S : 1C	7.5	20.7	12.0	0.0	40.2	158.3	47.3
PSS : RTC	7.9	20.7	6.0	6.0	40.6	197.5	58.4
C: RTS	8.0	20.7	6.0	6.0	40.7	210.8	62.2
S	7.4	20.7	12.0	0.0	40.1	146.0	43.7

Notations are same as given in Table 65

In wheat during 2008-09, the highest grain yield of 4.64 t/ha and lowest 3.41 t/ha of wheat were obtained in canal and all saline treatments, respectively (Table 67). The relative yields obtained were 87.1, 83.4, 98.9, 76.7, 89.0, 84.7 and 73.5 per cent in 1C:1S, 1S:1C, 2C:1S, 2S:1C, 1C:RTS, PSS:RTC and all saline treatments, respectively, as compared to the yield recorded in canal irrigation. Significant differences were also obtained in case of plant height, earhead/metre row length (mrl) and earhead length in saline treatment as compared to canal irrigation.

Similarly, during 2009-10 also the wheat grain yield reduced significantly in S (all saline), 2S:1C and 1C:RTS treatments as compared to canal (C) irrigation (Table 67). The highest yield of 5.00 t/ha and the lowest 3.45 t/ha of wheat were obtained in all canal and all saline treatments respectively. The relative yields obtained were 98.8, 95.8, 89.6, 84.9, 79.5, 69.6 and 68.9 per cent in 2C:1S, 1C:1S, 1S:1C, PSS: RTC (rest with canal), 1C: RTS (rest with saline), 2S:1C, and S treatments, respectively, as compared to the yield recorded in canal irrigation assumed to be 100 per cent.

Table 67. Growth and yield parameters of wheat as affected by different treatments

Treatments	Plant height (cm)		Earsheads/m row length		Length of earhead (cm)		Grain yield (t/ha)	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
C	84.67	74.33	82.67	69.33	12.77	11.66	4.64	5.00
1C: 1S	77.89	76.44	79.33	77.33	11.66	10.44	4.04	4.79
1S: 1C	80.89	72.55	77.00	71.33	11.22	11.10	3.87	4.48
2C:1S	88.00	77.66	86.67	80.66	12.78	10.77	4.59	4.94
2S:1C	72.55	70.66	71.67	75.33	10.89	10.89	3.56	3.48
PSS: RTC	83.44	76.11	78.00	84.66	11.44	10.44	4.13	4.25
C: RTS	83.44	76.44	74.00	72.33	11.33	10.67	3.93	3.98
S	70.22	71.55	69.00	67.66	10.66	11.22	3.41	3.45
CD (5%)	7.17	4.03	8.15	6.60	0.95	NS	0.62	0.52

Notations are same as given in Table 65

Salinity build-up during wheat crop

The salinity (EC_e) profiles at sowing of wheat during 2009-10 and at harvest of crop indicated the salt build-up with various modes of irrigations. The average EC_e of the soil profile upto 120 cm depth before the sowing of wheat varied from 3.84-7.09 dS/m in various treatments. The profile distribution of EC_e from surface to 120 cm depth showed decreasing trend in all the treatments being maximum in the surface layer before sowing as well as after harvesting. EC_e at the harvest during 2009-10 ranged from 3.70 (in layer 90-120, all canal irrigation treatment) to 10.80 dS/m (in layer 0-15, all saline irrigation treatment). Among the cyclic mode treatments, 2S:1C had the highest average salinity (6.85 dS/m) followed by 1S: 1C (5.91 dS/m) at the time of wheat harvest. It is ascribed to the more saline irrigations in this treatment than other cyclic treatments. Major accumulation of salts at wheat harvest was observed in 0-30 cm layers (Fig. 16).

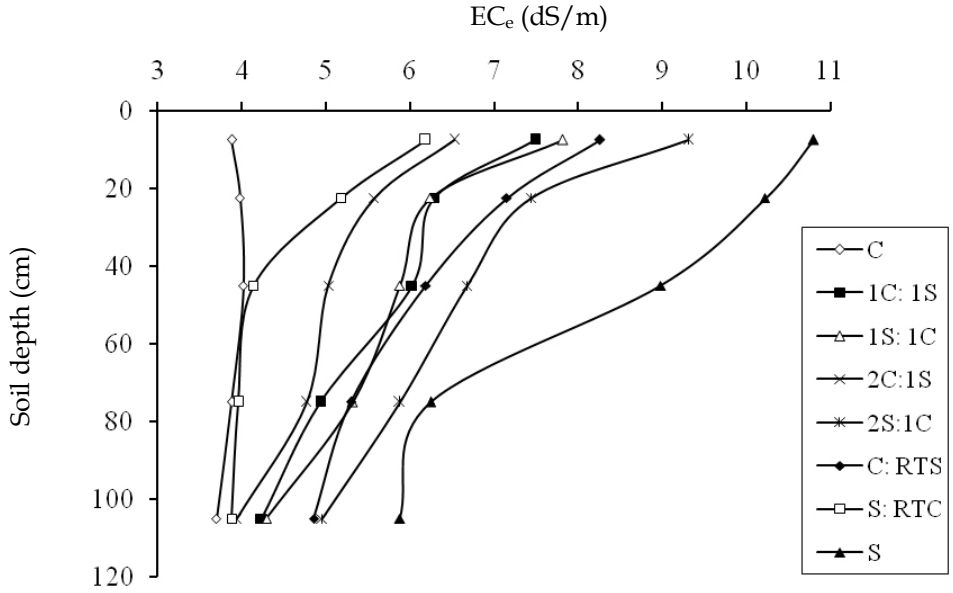


Fig. 16. Depthwise EC_e distribution in various treatments at harvest of wheat crop during 2009-10

Modeling and salinization of soil profile

By using Kapoor and Pal (1986) model, which is based on miscible displacement and evaporation, distribution of salts in different layers of root zone was predicted after the harvest of different crops considering irrigation with canal\saline water or rain. This model included upward capillary movement of soil solution, characterizing each soil layer by its field capacity and actual moisture

content of the profile at the time of irrigation. A brief description of the Kapoor and Pal model is given below:

The post redistribution salt concentration of i^{th} layer at field capacity after the j^{th} irrigation (CF_{ij}, dS/m) was estimated by

$$CF_{ij} = \frac{ST_{ij}}{F_i}(1 - ZD_{ij}) \quad (1)$$

ST_{ij}, the salt content (dS) of the i^{th} layer after the j^{th} irrigation was calculated using

$$ST_{ij} = ST_{i-1\,j}ZD_{i-1\,j} + SF_{ij-1} \quad (2)$$

Where $ST_{i\,j-1}(= CF_{i\,j-1}F_i)$ is the salt content (dS) of the i^{th} layer at field capacity F_i (cm) before the j^{th} irrigation, ZD_{ij}, the fraction of water drained from the i^{th} layer after the j^{th} irrigation, was given by

$$ZD_{ij} = \frac{D_{ij}}{D_{i-1\,j} + M_{i\,j-1}} \quad (3)$$

Where D_{ij}, the amount of water drained from the i^{th} layer after the j^{th} irrigation, was calculated as

$$D_{ij} = D_{i-1\,j} + M_{i\,j-1} - F_i \quad (4)$$

In which $M_{i\,j-1}$ is the moisture content (cm) of the i^{th} layer before the j^{th} irrigation.

Post evaporation salt content (dS) of the topmost layer (i = 1) after the j^{th} irrigation ($^{n}SF_{1j}$), when water moved up from the n^{th} layer, was estimated using

$$^{n}SF_{1j} = {}^{1}SF_{1j} + \sum_{2}^{n} {}^{n}ST_{2j}ZL_{2j} \quad (5)$$

With

$$^{n}ZL_{ij} = \frac{F_i - M_{ij}}{F_i} \qquad (i = n)$$

$$^{n}ZL_{ij} = \frac{F_n - M_{nj}}{F_n - M_{nj} + M_{ij}} \qquad (i < n)$$

As the fraction of water moved up from the i^{th} layer after the j^{th} irrigation, when movement of water took place from n^{th} layer.

$^{n}ST_{ij}$, the salt content (dS) of the i^{th} layer after the j^{th} irrigation, when water moved from the n^{th} layer to the i^{th} layer, before it further moved to the first layer, was calculated as

$$^{n}ST_{ij} = {}^{n-1}ST_{ij} + {}^{n}ST_{i+1\,j}\,{}^{n}ZL_{i+1\,j} \qquad (i < n) \quad (6)$$

Post evaporation salt content (dS) of the i^{th} layer (i =2, 3, …(n-1)), other than the topmost and the lowermost layers, after the j^{th} irrigation ($^{n}ST_{ij}$), when water moved up from the n^{th} layer, was estimated as

$$^{n}SF_{ij} = {}^{n}ST_{ij}(1 - {}^{n}ZL_{ij}) \quad (7)$$

The salt content (dS) of the lowermost layer (i = n) after the j^{th} irrigation was obtained from

$$^{n}SF_{ij} = {}^{n}ST_{ij}(1 - ZL_{ij}) \quad (8)$$

The experimental and the simulated EC_e values of soil at various depths for the years 2009 and 2009-10 after the harvest of cotton and wheat for cotton-wheat crop rotation under conjunctive use of saline waters are shown in Fig. 17 and 18, respectively. A comparison of the observed and the simulated EC_e profiles after the harvest of different crops showed that the trend and magnitude of the two curves were in good agreement except that there was some over prediction of EC_e in the top layer and under prediction in the second layer by the model. This may be due to assumption of the model that water evaporate from the top layer and a part of the solution which move from the lower layers move in solution phase. The average simulated EC_e of the profile after the harvest of different crops was slightly over predicted. This may be due to no consideration of salt uptake by the crop in model. Incomplete mixing of initial and incoming solutions in any layer nonuniform downward and upward movement of soil solution in pores of different sizes and selection of rate constants (which are dependent on temperature and moisture content) might have contributed to the trend and magnitude of disagreement between the experimental and the predicted EC_e values.

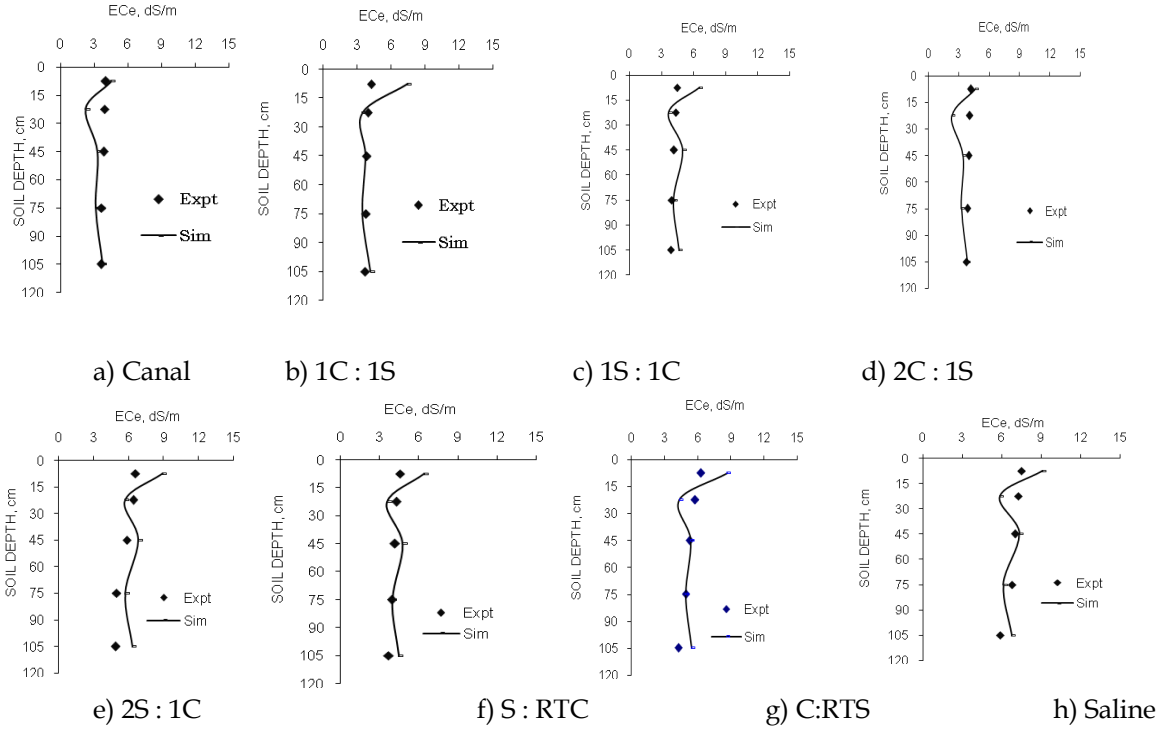


Fig. 17. Observed and simulated values of EC_e in cotton during 2009 in different treatments

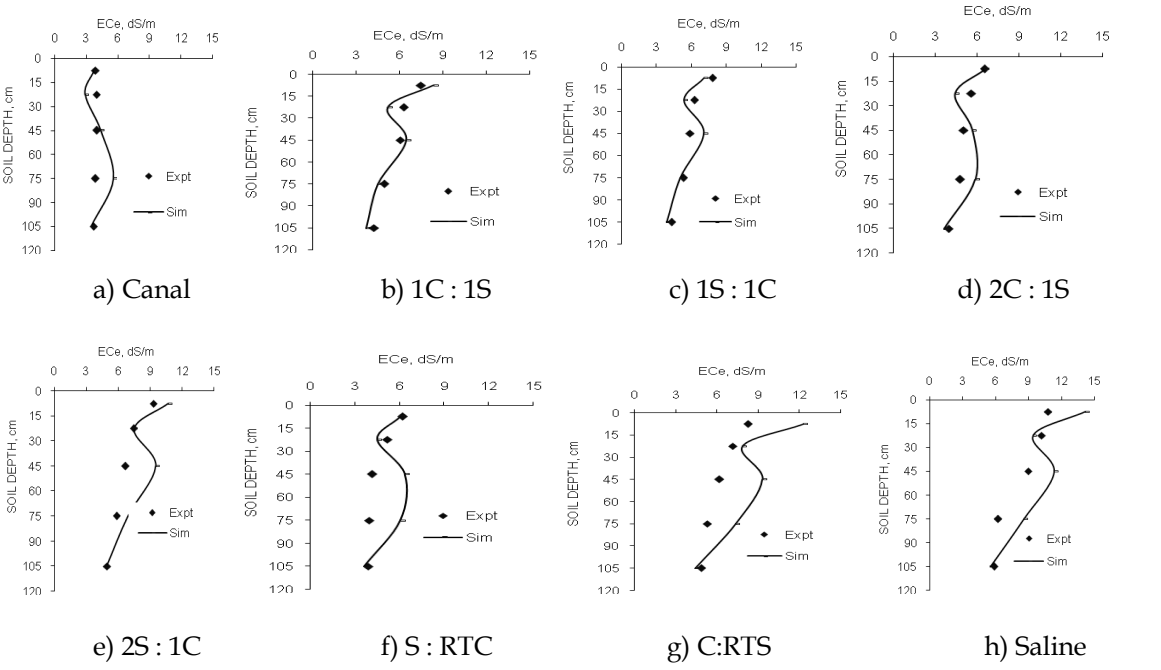


Fig. 18. Observed and simulated values of EC_e in wheat during 2009-10 in different treatments

Further, a comparison between the observed and simulated EC_e values of the soil profile (Fig. 19) in cotton and wheat crops revealed a good agreement. It can also be seen that when observed values of EC_e were plotted against values of EC_e simulated from the model for all soil layers, the points were randomly scattered about a line that was not very different from the line of perfect agreement. A linear statistical analysis of the results ($y = 1.232 x - 0.595$) and values of $R^2 = 0.652$ from all samplings suggested that predictions of the model were highly correlated with the observed ones. The value of slope close to 1 (1.232) and intercept close to zero (0.595) suggested that the overall simulation of the model were good.

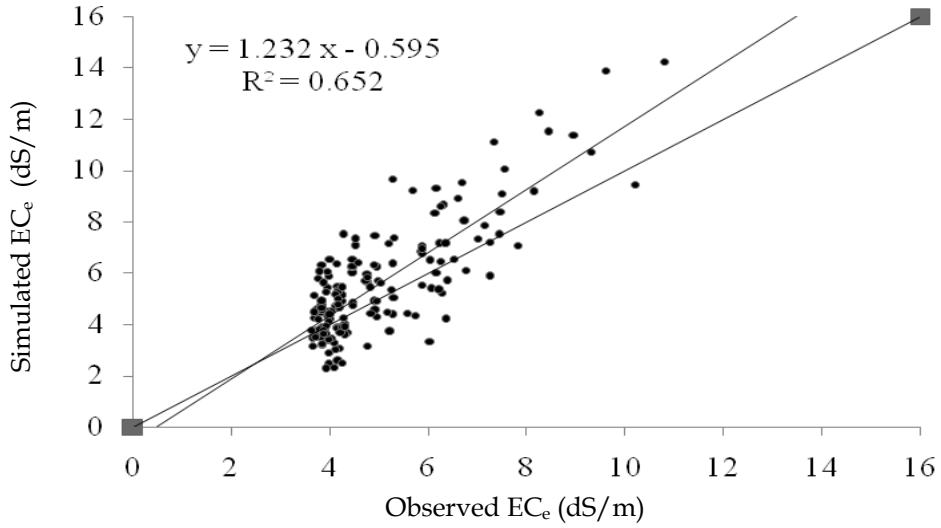


Fig. 19. Observed vs. simulated EC_e values for cotton-wheat for different years

Strategies for Conjunctive Use of Saline and Canal Water in Pearl millet-Mustard Rotation - Hisar

In pearl millet crop during 2008-09, irrigation with saline water reduced the plant height, earhead per metre row length, earhead length and grain yield of pearl millet crop significantly as compared to irrigation with canal water. The grain yield of pearl millet ranged from 2.33-3.64 t/ha in different irrigation treatments (Table 68). The relative yields obtained under 2S:1C and all saline treatments were 73.4 and 64.0 per cent, respectively as compared to yield obtained in canal irrigation.

Table 68. Growth and yield parameters of pearl millet as affected by different treatments (2008)

Treatments	Plant height (cm)	Earhead/m row length	Earhead length (cm)	Grain yield (t/ha)
C	200.33	27.33	25.56	3.64
1C: 1S	187.67	26.00	22.67	3.39
1S: 1C	179.89	24.33	24.11	3.04
2C:1S	192.34	27.33	24.56	3.53
2S:1C	176.11	23.00	24.22	2.67
S: RTC	181.89	23.00	22.78	3.10
C: RTS	180.44	24.33	23.78	3.02
S	169.00	22.00	23.11	2.33
CD (5%)	12.21	2.98	NS	0.59

Similarly, during 2009-10, saline water irrigation reduced the plant height, earhead per metre row length, earhead length and grain yield of pearl millet crop significantly as compared to irrigation with canal water. The grain yield of pearl millet ranged from 2.89-3.89 t/ha in different irrigation treatments (Table 69). The relative yields obtained under 2S:1C and all saline treatments were 78.4 and 78.1 per cent, respectively as compared to yield obtained in canal irrigation. Minimum plant height (148.77 cm) of pearl millet crop was obtained under saline irrigation treatment which was significantly lower than other treatments except 2S:1C treatment. Maximum plant height (205.21 cm) was recorded under all canal irrigation treatment. The number of earheads per mrl ranged from 22.66-28.33 (Table 69). The maximum earhead length (26.99 cm) was recorded in 2C:1S treatment. However, the differences in earhead length among various treatments were non-significant.

Table 69. Growth and yield parameters of pearl millet as affected by different treatments (2009)

Treatments	Plant height (cm)	Earhead /m row length	Earhead length (cm)	Grain yield (t/ha)
C	205.21	28.33	25.68	3.70
1C: 1S	196.10	27.00	26.66	3.61
1S: 1C	175.00	25.00	24.00	3.17
2C:1S	201.44	27.66	26.99	3.89
2S:1C	166.77	24.00	23.44	2.90
S: RTC	182.67	23.66	25.88	3.33
C: RTS	175.00	25.00	26.33	3.11
S	148.77	22.66	24.77	2.89
CD (5%)	20.36	2.69	NS	0.27

In mustard crop, during 2008-09, significantly lower plant height, siliquae/plant and seed yield were recorded in saline irrigation treatment, 2S:1C as compared to canal water (Table 70). The relative yield obtained under 1C:1S, 1S:1C, 2C:1S, 2S:1C, S:RTC, C:RTS and S treatments were 92.3, 86.1, 96.4, 83.9, 90.1, 85.0 and 78.5 per cent, respectively. The seed yield of mustard ranged from 2.15-2.74 t/ha in different irrigation treatments. The plant height ranged from 156.35 cm to 184.55 cm in saline and canal irrigation, respectively. Maximum number of siliquae per plant (187) were obtained under canal irrigation treatment, whereas, minimum were recorded under all saline treatment (154).

Table 70. Growth and yield parameters of mustard as affected by different treatments (2008-09)

Treatments	Plant height (cm)	Siliquae/ plant	Seeds/ siliquae	Test weight (g)	Seed yield (t/ha)
C	182.22	187.00	13.33	6.34	2.74
1C: 1S	172.22	181.00	13.00	6.66	2.53
1S: 1C	175.51	175.00	12.67	5.90	2.36
2C:1S	174.22	185.00	13.00	5.95	2.64
2S:1C	163.67	157.00	11.00	6.09	2.30
S: RTC	184.55	172.00	11.00	6.78	2.47
C: RTS	181.89	176.33	11.00	5.95	2.33
S	156.35	154.00	10.67	6.27	2.15
CD (5%)	11.85	13.58	1.44	NS	0.30

Similarly during 2009-10, significantly lower plant height, siliquae/plant and seed yield was recorded in saline irrigation treatment, 2S:1C as compared to canal water treatment (Table 71). The relative yield obtained under 1C:1S, 1S:1C, 2C:1S, 2S:1C, S:RTC, C:RTS and S treatments were 91.6, 84.6, 95.3, 81.3, 89.6, 86.3 and 75.3 per cent, respectively. The seed yield of mustard ranged from 2.25-2.99 t/ha in different irrigation treatments. The plant height ranged from 158.2 to 191.0 cm in saline and canal irrigation, respectively. Maximum numbers of siliquae per plant (197) were obtained under 2C:1S treatment whereas minimum were recorded under all saline treatment (138.3).

The mean EC_e of the soil profile down to 120 cm before sowing of mustard varied from 3.60-6.00 dS/m in various treatments (Fig. 20). The EC_e ranged from 3.56–6.46 dS/m in 0-15 cm layer and from 3.84 – 9.86 dS/m in 15-30 cm layer at the harvest of the crop (Fig. 20). The highest EC_e (9.86 dS/m) was observed in case all saline water irrigation treatment in 15-30 cm layer after the harvest of crop. The electrical conductivity of soil saturation extract was higher in saline water irrigated plots than cyclic mode of irrigation. Among the cyclic mode treatments, 2S: 1C had the highest mean salinity (7.47 dS/m) followed by 1S: 1C (5.70 dS/m) at harvest. Major accumulation of salts was observed in the upper layer of the soil irrespective of the irrigation treatments which decreased slowly and continuously (Fig. 20b).

Table 71. Growth and yield parameters of mustard as affected by different treatments (2009-10)

Treatments	Plant height (cm)	Siliquae/ plant	Test weight (g)	Seed yield (t/ha)
C	191.00	195.33	5.73	2.99
1C: 1S	176.89	191.66	5.76	2.74
1S: 1C	162.22	178.66	5.82	2.53
2C:1S	186.99	197.00	6.10	2.85
2S:1C	166.11	144.33	5.82	2.43
S: RTC	173.88	170.00	5.81	2.68
C: RTS	189.88	160.33	5.94	2.58
S	158.22	138.33	6.05	2.25
CD (5%)	14.45	7.64	NS	0.42

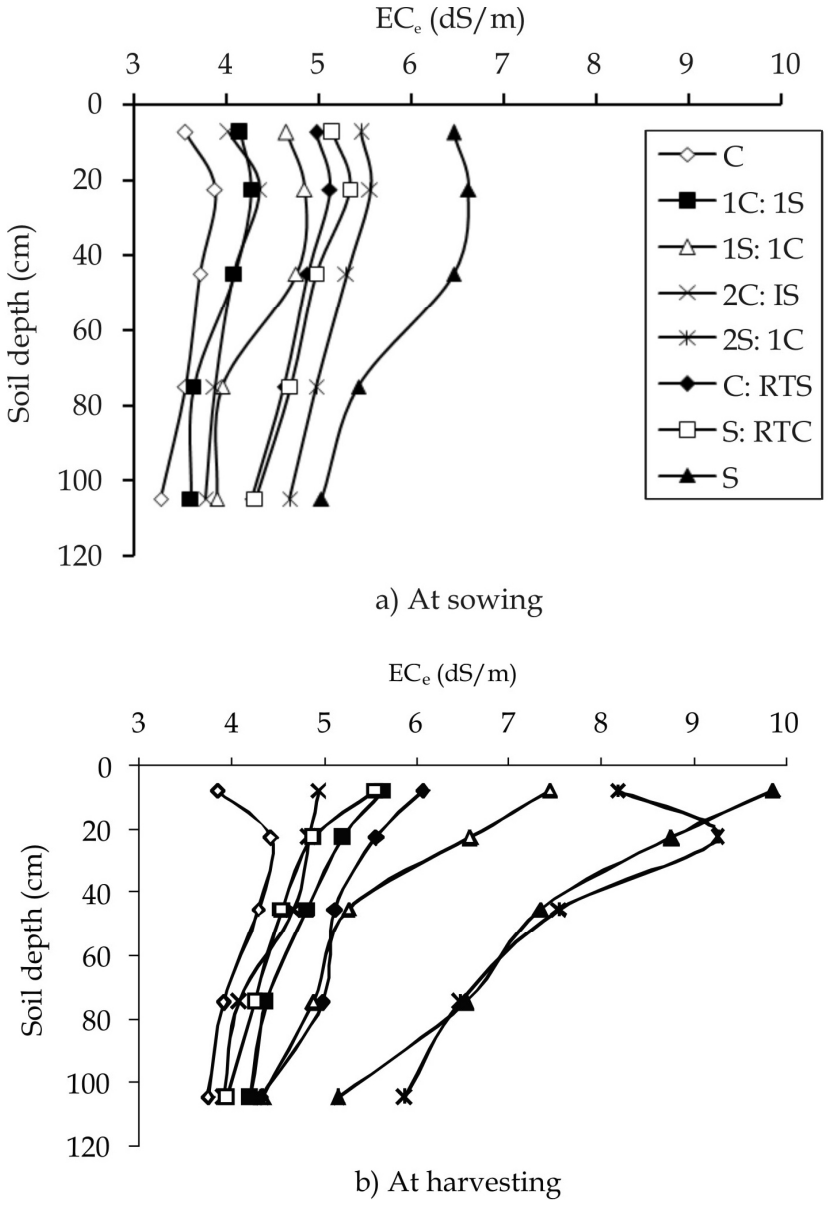


Fig. 20. Depthwise EC_e distribution in various treatments a) before sowing and b) at the harvest of mustard crop during 2009-10

Impact of Agra Canal Water on Ground water Quality, Soil Properties and Crop Performance- Agra

The Agra canal and drinking water samples were collected every month of the year 2009-2010 from different locations of Agra canal i.e. Okhala (Delhi), Palwal (Haryana), Kosi, Mathura (UP), Goverdhan, Mathura (UP) and Bichpuri, Agra (UP) which is being used for irrigation for vegetables, cereals and pulse crops. The water samples were categorized in three seasons and analyzed using standard techniques as mentioned in APHA (1999). The results presented in Table 72a and b and discussed in light of the different standards for discharge of sewage water set by WHO (1993) and IS:10500-91.

Table 72a. Agra canal water analysis for Okhla (Delhi), Palwal (Haryana) and Kosi (UP)

Particulars	Okhla			Palwal			Kosi		
	After rains	Winter season	Before rains	After rains	Winter season	Before rains	After rains	Winter season	Before rains
pH	7.4	7.3	7.0	7.4	7.1	7.1	7.4	7.4	7.1
EC (dS/m)	1.4	1.9	1.5	1.7	1.9	1.9	1.4	1.8	1.8
BOD (mg/l)	26	37	42	31	27	27	40	24	23
COD (mg/l)	27	27	24	97	99	93	97	95	89
CO_3 (mg/l)	15	15	8	-	-	-	5	15	-
HCO_3 (mg/l)	156	375	235	302	293	262	275	293	452
Chloride (mg/l)	168	159	146	200	172	194	172	153	191
Sulfate (mg/l)	654	658	715	658	606	713	420	640	594
Nitrate (mg/l)	-	-	-	-	-	-	-	-	-
Calcium (mg/l)	52	55	59	55	62	61	64	44	60
Magnesium(mg/l)	15	18	21	46	25	30	40	48	26
Sodium (mg/l)	94	101	96	187	124	117	185	111	148
Potassium (mg/l)	19	14	15	18	15	17	11	13	16
Copper (mg/l)	-	-	-	-	-	-	-	-	-
Manganese(mg/l)	35.7	36.3	40.6	41.3	38.5	39.4	46.6	38.6	39.3
Zinc (mg/l)	0.03	0.07	0.02	0.02	0.03	0.03	0.02	0.02	0.02
Cobalt (mg/l)	0.03	0.03	0.04	0.03	0.03	0.02	0.04	0.02	0.03
Iron (mg/l)	-	-	-	-	-	-	-	-	-
SAR (mmol/l) $^{1/2}$	3.0	3.2	2.8	4.5	3.4	3.1	4.56	3.0	3.9
RSC (meq/l)	0.05	2.3	-	-	-	-	-	0.9	2.3

Table 72b. Agra canal water analysis for Goverdhan, Mathura and Bichpuri, Agra (UP)

Particulars	Goverdhan			Bichpuri		
	After rains	Winter season	Before rains	After rains	Winter season	Before rains
pH	7.9	7.3	7.2	7.2	7.3	7.3
EC (dS/m)	1.6	1.7	2.3	1.1	1.8	1.6
BOD (mg/l)	15	14	20	21	21	31
COD (mg/l)	83	95	89	83	74	78
CO_3 (mg/l)	30	5	12	3	2	-
HCO_3 (mg/l)	186	401	320	180	229	162
Chloride (mg/l)	131	193	230	166	150	156
Sulfate (mg/l)	594	535	809	352	659	599
Nitrate (mg/l)	-	-	-	-	-	-
Calcium (mg/l)	64	51	61	60	49	54
Magnesium (mg/l)	25	26	34	33	33	20
Sodium (mg/l)	141	102	183	148	124	118
Potassium (mg/l)	9	14	18	6	8	9
SAR (mmol/l) $^{1/2}$	3.8	2.9	4.7	3.9	3.4	3.9
RSC (meq/l)	NIL	NIL	NIL	NIL	NIL	NIL

Characterization of ground water at Agra canal sites

Groundwater samples were collected from five different sites of Agra canal i.e. Okhala (submersible), Pawal (tube well), Kosi (submersible), Goverdhan (tube well) and Bichpuri (hand pump). These water samples were analyzed and compared with the drinking water standards as laid down by WHO (1993) and IS (1991), Table 73, 74, 75.

Table 73. Drinking water standards as laid down by WHO (1993) and IS:10500-91

Parameters	WHO (1993)	IS:10500-91
pH	6.5-8.5	6.5-8.5
EC (µS/cm)	1400	-
TDS (mg/l)	1000	500
Turbidity (NTU)	<5	5 to 10
BOD (mg/l)	5	-
CO_3 as $CaCO_3$ (mg/l)	-	-
HCO_3 as $CaCO_3$(mg/l)	120	-
Chloride (mg/l)	250	250-1000
Sulphate (mg/l)	250	150
Nitrate (mg/l)	45	40
Phosphorus (mg/l)	0.1	-
TH as $CaCO_3$ (mg/l)	500	300
Calcium (mg/l)	100	75
Magnesium (mg/l)	150	30
Sodium (mg/l)	200	-
Potassium (mg/l)	12	
Cadmium (mg/l)	0.003	-
Copper (mg/l)	1-2	0.05
Manganese (mg/l)	0.1-0.5	0.1
RSC (meq/l)	Nil	Nil

Table 74. Ground water analysis of Okhla submersible, Palwal tube well and Kosi submersible

Particulars	Okhla			Palwal			Kosi		
	After rains	Winter season	Before rains	After rains	Winter season	Before rains	After rains	Winter season	Before rains
pH	7.4	7.5	7.4	7.9	7.7	7.7	7.7	8.0	7.7
EC (dS/m)	2.5	2.4	2.3	1.1	1.8	1.6	4.3	2.5	1.7
BOD (mg/l)	6	4	8	3	3	3	3	4	2
COD (mg/l)	17	18	18	19	22	18	10	14	8
CO_3 (mg/l)	9	-	-	9	7	-	13	9	10
HCO_3 (mg/l)	363	278	149	317	229	168	451	427	397
Chloride (mg/l)	168	128	90	184	149	146	530	416	456
Sulfate (mg/l)	936	969	984	845	728	724	1119	777	328
Nitrare (mg/l)	-	-	-	-	-	-	-	-	-
Calcium (mg/l)	36	36	30	44	76	78	36	38	33
Magnesium(mg/l)	72	37	64	51	48	63	63	56	34
Sodium (mg/l)	151	142	135	164	193	128	145	116	203
Potassium (mg/l)	11	15	13	22	22	15	17	10	15
Copper (mg/l)	-	-	-	-	-	-	-	-	-
Manganese (mg/l)	51.7	41.7	46.9	-	-	-	51.2	65.4	50.5
Zinc (mg/l)	0.03	0.02	0.02	-	-	-	0.03	0.03	0.02
Cobalt (mg/l)	0.02	0.03	0.01	-	-	-	0.03	0.03	0.02
Iron (mg/l)	3.5	3.9	4.3	5.1	4.7	2.5	3.5	4.0	5.8
RSC (meq/l)	0.9	1.6	-	-	-	-	-	-	-

Table 75. Ground water analysis of Goverdhan tube well and Bichpuri hand pump

Particulars	Goverdhan			Bichpuri		
	After rains	Winter season	Before rains	After rains	Winter season	Before rains
pH	7.8	7.8	7.9	7.8	8.1	7.6
EC (dS/m)	3.6	4.4	2.5	2.6	2.2	2.8
BOD (mg/l)	5	5	6	4	4	5
COD (mg/l)	10	11	9	7	6	4
CO_3 (mg/l)	26	8	-	16	11	5
HCO_3 (mg/l)	367	445	343	314	381	561
Chloride (mg/l)	166	193	57	230	172	356
Sulfate (mg/l)	140	1794	809	895	779	841
Nitrare (mg/l)	-	-	-	-	-	-
Calcium (mg/l)	60	76	47	62	23	45
Magnesium (mg/l)	91	100	42	84	60	68
Sodium (mg/l)	130	131	120	267	123	281
Potassium (mg/l)	15	11	12	5	3	7
SAR (mmol/l) $^{1/2}$	2.7	2.9	3.2	5.5	2.8	6.1
RSC (meq/l)	Nil	NIil	Nil	Nil	Nil	Nil

Study revealed that several water samples have higher salinity. Among different cations, calcium, magnesium and sodium showed lower range, while anions like carbonate, chloride and sulphate showed higher concentration. Heavy metals also showed higher concentration due to contamination of domestic and industrial effluents.

Assessment of Irrigation with Treated Sewage on Soil, Crop and Ground Water Quality - Agra

The sewage and drinking water samples were collected every month during 2009-2010 from different location of STP Dandhupura, district Agra which is being used for irrigating different crops. The water samples were analyzed and categorized in three seasons.

The sewage water samples of Agra city were collected at sewage station Dandhupura without treatment (at inlet) before rains, after rains and during winter season. The water showed high EC values after rains. A slight decreasing trend in pH (6.9-7.7) was observed during winter. BOD ranged from 2.4 - 221 mg/l but the highest value (221 mg/l) was observed during winter. The biocarbonate increased before rains while chloride increased after rains. Calcium was the dominant cation before rains. RSC ranged from 0.5-2.2 meq/1. Heavy metals i.e. copper ranged from 0.04-0.09 mg/l, manganese ranged from 82.2-104.9 mg/l, zinc ranged from 0.07-0.09 mg/l, cobalt from 0.01-0.07 mg/l and iron ranged from 0.04-0.07 mg/l (Table 76).

The treated sewage water samples were collected at STP ponds with primary treatment. The salinity of water ranged from 3.4 to 3.7 dS/m being highest before rains. A slightly decreased pH (7.2-7.5) was observed during winter season. BOD ranged from 30 to 32 mg/l with highest value (32 mg/l) during winter season. The carbonate was observed in outlet water after rains only. Bicarbonate ranged from 565 to 702 mg/l and chloride ranged from 69 to 471 mg/l. Nitrate ranged from 287-340 mg/l, calcium ranged from 65 to 80 mg/l, magnesium ranged from 98 to 104 mg/l. Sodium content was higher and ranged from 432 to 479 mg/l, potassium ranged from 36 to 38 mg/l. SAR ranged from 7.6 to 8.6, but RSC was absent in all water samples. Heavy metals i.e. copper ranged from 0.02 to 0.03 mg/l, manganese ranged from 87.9 to 97.1 mg/l, zinc ranged from 0.02 to 0.03 mg/l, cobalt ranged from 0.02-0.03 mg/l and iron ranged from 0.01 to 0.01 mg/l.

The treated sewage water samples were collected at 1 km distance from STP during whole year. The water has high EC ranging from 3.3 to 4.1, being highest during winter season. BOD ranged from 14 to 29 mg/l, highest observed before rains. Carbonate and bicarbonate observed in all samples. Nitrate

ranged from 181 to 233 mg/l, calcium 38-93 mg/l, magnesium 92-114 mg/l[1], sodium 322-479 mg/l, potassium 30-42 mg/l. RSC was not observed but SAR ranged from 6.2 to 8.7 (Table 76).

Table 76. Sewage water analysis at Dhadhupura STP inlet, outlet and 1km away from STP

Particulars	At inlet of STP			At outlet of STP			At 1Km distance from STP		
	After rains	Winter season	Before rains	After rains	Winter season	Before rains	After rains	Winter season	Before rains
pH	7.7	6.9	7.4	7.3	7.2	7.5	7.6	7.7	7.2
EC (dS/m)	3.4	3.6	4.7	3.4	3.6	3.7	3.3	4.1	3.7
BOD (mg/l)	204	221	221	30	32	30	15	14	30
COD (mg/l)	483	516	509	118	129	126	58	91	63
CO_3 (mg/l)	30	-	-	51	-	-	36	45	17
HCO_3 (mg/l)	702	723	995	570	665	702	506	580	467
Chloride (mg/l)	516	60	83	471	208	69	496	189	69
Sulfate (mg/l)	289	792	1456	480	900	1142	444	1193	1277
Nitrate (mg/l)	405	341	326	340	284	287	206	181	233
Calcium (mg/l)	97	92	112	65	82	80	38	46	93
Magnesium(mg/l)	77	96	100	104	75	98	114	96	92
Sodium (mg/l)	478	438	457	479	447	432	479	372	322
Potassium (mg/l)	39	36	37	38	36	37	42	35	30
Copper (mg/l)	0.09	0.08	0.04	0.02	0.03	0.02	-	-	-
Manganese(mg/l)	89.7	82.2	104.9	87.9	90.7	97.1	-	-	-
Zinc (mg/l)	0.07	0.07	0.09	0.02	0.02	0.03	-	-	-
Cobalt (mg/l)	0.01	0.01	0.07	0.02	0.03	0.03	-	-	-
Iron (mg/l)	0.07	0.04	0.06	0.01	-	0.01	-	-	-
SAR (mmol/l) $^{1/2}$	8.8	7.7	7.6	8.5	8.6	7.6	8.7	7.2	6.2
RSC (meq/l)	1.3	0.5	2.2	-	-	-	-	-	-

Drinking water samples were collected from submersible near to sewage water canal of STP Kuankheda village, district Agra. The analysis of samples showed that pH ranged from 7.8 to 8.1. The EC was very high (3.3-3.7 dS/m). Among anions chloride was the dominant ion and ranged from 59 to 526 mg/l. Sulphate ranged from 468 to 1188 mg/l. Higher concentration of calcium, magnesium, sodium and potassium were reported as per the standard limit of WHO and IS. RSC of water was 1.2-6.2 and SAR 11.6-14.1. Heavy metals were also higher; manganese 40.4-49.4 mg/l zinc 0.02-0.12 mg/l, cobalt 0.01-0.02 mg/l while copper and iron was absent (Table 77).

The drinking water samples collected from handump at Kuankheda revealed that pH was normal whereas, EC ranged from 3.4 to 3.7 dS/m, which was higher than the limits set by WHO and IS. Bicarbonate also showed higher values. Similar pattern was observed in case of chloride. The sulphate content in the water ranged from 370 to 1195 mg/l and nitrate from 234 to 240 mg/l, potassium was high in drinking water and ranged from 30 to 40 mg/l.

The drinking water samples were also collected from tube well of Budhana village and analysis results presented in Table 77.

The yield of the crops irrigated with treated sewage water and fresh ground water were compared (Table 78). The yield increase in most crops was in the range of 10-14% which could be due to high organic carbon and available nitrogen in the treated sewage water.

Table 77. Ground water analyses for STP site areas

Particulars	Kuankheda submersible			Kuankheda handpump			Budhana Tube well		
	After rains	Winter season	Before rains	After rains	Winter season	Before rains	After rains	Winter season	Before rains
pH	7.7	6.9	7.4	7.3	7.2	7.5	7.6	7.7	7.2
EC (dS/m)	3.4	3.6	4.7	3.4	3.6	3.7	3.3	4.1	3.7
BOD (mg/l)	204	221	221	30	32	30	15	14	30
COD (mg/l)	483	516	509	118	129	126	58	91	63
CO_3 (mg/l)	30	-	-	51	-	-	36	45	17
HCO_3 (mg/l)	702	723	995	570	665	702	506	580	467
Chloride (mg/l)	516	60	83	471	208	69	496	189	69
Sulfate (mg/l)	289	792	1456	480	900	1142	444	1193	1277
Nitrate (mg/l)	405	341	326	340	284	287	206	181	233
Calcium (mg/l)	97	92	112	65	82	80	38	46	93
Magnesium(mg/l)	77	96	100	104	75	98	114	96	92
Sodium (mg/l)	478	438	457	479	447	432	479	372	322
Potassium (mg/l)	39	36	37	38	36	37	42	35	30
Copper (mg/l)	0.09	0.08	0.04	0.02	0.03	0.02	-	-	-
Manganese(mg/l)	89.7	82.2	104.9	87.9	90.7	97.1	-	-	-
Zinc (mg/l)	0.07	0.07	0.09	0.02	0.02	0.03	-	-	-
Cobalt (mg/l)	0.01	0.01	0.07	0.02	0.03	0.03	-	-	-
Iron (mg/l)	0.07	0.04	0.06	0.01	-	0.01	-	-	-
SAR (mmol/l) $^{1/2}$	8.8	7.7	7.6	8.5	8.6	7.6	8.7	7.2	6.2
RSC (meq/l)	1.3	0.5	2.2	-	-	-	-	-	-

Table 78. Comparison of crop yields under treated sewage and fresh ground water at farmer's field

Crops	Treated sewage water irrigated crops yield (t/ha)	Fresh ground water irrigated crops yield (t/ha)	Yield increase in treated sewage water (%)
Mustard	2.80	2.50	11
Wheat	4.20	3.80	10
Pearl millet	2.90	2.50	13
Cauliflower	6-10 (mid) 22-25 (late)	4-9 (mid) 16-22 (late)	10 (mid) 12 (late)
Cabbage	7-8	5-7	13
Carrot	22-28	20-24	14
Cowpea	5-8 (green pod) 1-1.5 (grain)	4-7 (green pod) 0.9-1.3 (grain)	13 (green pod) 13 (grain)
Knol-knol	20-25	18-22	12
Onion	24-28	22-24	14
Palak	6-10	4-9	10
Radish	5-7	3-5	14
Spinach	6-8	3-7	13

The soil samples were collected at sowing and harvesting of pearl millet, wheat, mustard, potato, cauliflower, coriander and spinach at 0-15 and 15-30 cm depth. The EC_e varied from 2.5-2.9 dS/m and pH 7.4-8.0. Soil analysis showed that available N and organic carbon (%) increased with the irrigation of the crops using treated sewage water over initial available N and organic carbon content (Table 79).

Table 79. Soil analysis at sowing and harvesting of crops irrigated with treated sewage water

Crops	Soil depth (cm)	At sowing				At harvesting			
		EC_e	pH	Av. N (kg/ha)	OC (%)	EC_e	pH	Av. N (kg/ha)	OC (%)
Pearl millet	0-15	2.8	7.8	220	0.52	2.5	7.7	210	0.50
	15-30	2.6	7.7	214	0.48	2.4	7.6	208	0.48
Wheat	0-15	2.8	7.9	232	0.55	2.5	7.8	225	0.52
	15-30	2.7	7.6	218	0.52	2.5	7.7	209	0.51
Mustard	0-15	2.8	8.0	234	0.55	2.6	7.6	224	0.48
	15-30	2.5	7.8	223	0.50	2.7	7.5	210	0.47
Potato	0-15	2.8	7.5	238	0.62	2.4	7.4	232	0.58
	15-30	2.6	7.4	228	0.60	2.4	7.6	225	0.55
Cauliflower	0-15	2.9	7.9	242	0.68	2.6	7.6	234	0.64
	15-30	2.7	7.8	232	0.65	2.5	7.4	228	0.62
Coriander	0-15	2.8	7.7	234	0.62	2.7	7.6	230	0.58
	15-30	2.6	7.6	223	0.55	2.6	7.5	224	0.52
Spinach	0-15	2.7	7.8	232	0.58	2.6	7.5	231	0.55
	15-30	2.5	7.6	222	0.55	2.5	7.6	215	0.51
Initial soil	0-15	2.7	7.5	198	0.32	2.6	7.7	196	0.30
	15-30	2.6	7.6	191	0.28	7.6	7.8	189	0.27

Effect of Sea Water Intrusion on Ground Water Quality in Coastal Belt of Krishna, AP - Bapatla

A plan was prepared for the collection of water samples of the Krishna Zone. Four places viz., Machilipatnam, Bapatla, Nizampatnam and Kanuparthi near the sea were fixed and following villages were selected for collection of water samples.

S_1 :Manginapudi, Chilakalapudi, Machilipatnam, Guduru and Nidumolu villages and fixed GPS points.

S_2 :Suryalanka, Muttaipalem, Bapatla, Jammulapalem, Appapuram and Kakumanu villages and fixed GPS points

S_3 : Nizampatnam, Pallepalem, Alluru, Alakapuram, Pittalavanipalem, RB Palem and Kavuru villages and fixed GPS points.

S_4 : Kanuparthi, Ammanabrolu, Agraharam and Naguluppalapadu villages and fixed GPS points

One hundred and twenty water samples were collected by fixing GPS points along the coastal region of Krishna Zone of Andhra Pradesh. Four points were fixed at Machilipatnam, Nizampatnam, Suryalanka and Kanuparthi and from these points samples were collected at a distance of 5, 10, 15, 20 km from the sea. The analysis of ground water samples (December 2008 and December 2009) revealed that there is no intrusion of sea water during monsoon period. The pH and EC values of ground water samples colleted during June and December, 2009 were 7.00 to 9.10; 6.98 to 8.41 and 0.57 to 12.90; 0.19 to 16.94, respectively. It was found that the salt content is moderately high in majority of the samples (Table 80). Further collection of data and analysis would help in understanding of the sea water intrusion in the region.

Table 80. Ionic ratios of good quality water and sea water

Ionic ratio	Good quality water	Sea water
Ca/Mg	3.72	0.18
Ca/Na	3.74	0.04
Mg/Na	3.85	0.26
Ca/SO_4	0.41	3.16
Mg/HCO_3	0.52	18.96
Cl/HCO_3	0.20	65.72
SO_4/HCO_3	0.45	7.10
HCO_3/SO_4	2.32	0.08
HCO_3/Cl	4.58	0.007
Cl/SO_4	0.45	9.85

Survey and Minimization of Adverse Effects of Nitrate in Ground Water - Bapatla

Sixteen ground water samples were collected from highly fertilized areas of Guntur district covering Kolluru, Kakumanu, Karlapalem, Bhattiprole, Vemuru, Cherukupalli, Bapatla mandals growing commercial crops. Nine samples were collected from Challapalli, Vuyyuru, Penamaluru and Mopidevi mandals of Krishna district. The NO_3 content ranged from 0.9 to 22.3 ppm in Guntur district (Table 81) and 1.1 to 10.8 ppm in Krishna district (Table 82). In Guntur district 44 per cent of samples showed nitrate above permissible limit of 15 ppm while in Krishna district all the samples were in safer level of below 15 ppm. In Guntur district, pH ranged from 6.9 to 9.7, EC ranged from 0.50 – 3.69 dS/m, CO_3 ranged from nil to 4.4 meq/l, HCO_3 ranged from 1.2 to 8.0 meq/l, Cl ranged from 1.2 to 16.4 meq/l, SO_4 ranged from 1.0 to 6.6 meq/l, while among cations Ca ranged from 1.2 to 14.8 meq/l, Mg ranged from 0.4 to 12.0 meq/l, Na ranged from 1.95 to 17.69 meq/l and traces of K (Table 83).

In Krishna district, the pH ranged from 7.7 to 8.2, EC_e ranged from 0.74 to 2.41 dS/m. The SAR was within the safe limit of 10 in both districts while RSC was nil to 4.2 meq/l in Guntur district and in within the safe limit of <2.5 meq/l in Krishna district (Table 83).

Table 81. Nitrate content in different bore wells in Guntur district

Name of the village	Name of the mandal	Name of crop	NO_3 (ppm)
Pedalanka	Kolluru	Banana	22.3
Pedalanka	Kolluru	Drinking water	15.0
Pedalanka	Kolluru	Drinking water	12.9
Pedalanka	Kolluru	Turmeric	22.1
Pedalanka	Kolluru	Turmeric	22.2
Appapurum	Kakumanu	K.w. Canal water	0.9
Patanandaipalem	Karlapalem	Chillies	20.0
Dammannavaripalem	Karlapalem	Ground nut	10.3
Thurpupalem	Bhattiprole	Turmeric	1.0
Vemuru	Vemuru	Maize	1.1
Rambotlavaripalem	Cherukupalli	Brinjal	16.0
Timmareddypalem	Karlapallem	Beans	21.0
SWS, Bapatla	Bapatla	Rice	11.8
Orchard Block, A.G. Farm	Bapatla	Mango	15.0
Floriculture Block, A.G. Farm	Bapatla	Rose	15.6
Vishnupuram (East Bapatla)	Bapatla	Water melon	12.0

Table 82. Nitrate content in different bore wells in Krishna district

Name of the village	Name of the mandal	Name of crop	NO_3 (ppm)
CDC farm, Challapalli	Challapalli	Sugarcane	9.5
CDC farm, Challapalli	Challapalli	Sugarcane	4.2
Lankapalli	Challapalli	Paddy	10.8
Gandigunta	Vuyyuru	Sugarcane	8.6
Pedaogirala	Vuyyuru	Sugarcane	3.1
Poranki	Penamaluru	Turmeric	5.6
Vuyyuru	Vuyyuru	Sugarcane	1.1
Vuyyuru	Vuyyuru	Sugarcane	3.7
Mopidevi	Mopidevi	Tomato	2.2

Permissible limit of NO_3 in ground water : 15 ppm

Table 83. Chemical composition of ground water of Guntur and Krishna districts

Parameters	Guntur district	Krishna district
pH	6.9-9.7	7.7-8.2
EC (dS/m)	0.5-3.69	0.74-2.41
CO_3 (meq/l)	0.0-4.4	0-1.0
HCO_3 (meq/l)	1.2-8.0	3.3-11.3
Cl (meq/l)	1.2-16.4	2.0-10.0
SO_4 (meq/l)	1.0-6.6	0.23-1.80
Ca (meq/l)	1.2-14.8	0.80-7.6
Mg (meq/l)	0.4-12.0	1.6-7.2
Na (meq/l)	1.95-17.69	2.4-10.75
K (meq/l)	0.01-0.09	0.4-0.17
SAR (meq/l)	0.96-6.59	1.62-5.51
RSC (meq/l)	0.0-4.2	0-0.28
NO_3 (ppm)	0.9-22.3	1.1-10.8

Survey and Minimization of Adverse Effects of Fluoride in Ground Water - Bapatla

Sixty two groundwater samples were collected from Prakasam district covering 16 mandals in Ongole division and analysed for pH, EC, cations, anions, SAR and RSC. EC_e ranged from 0.45 to 11.13 dS/m and pH from 7.06 to 9.10. The fluoride content ranged from 0.75 to 4.5 ppm, highest 4.5 ppm was recorded in Sankarapuram village of Mundlamuru mandal while the lowest value of 0.75 ppm was recorded in Dharmavaram village Addanki mandal. 69 per cent of ground water samples exceeded the permissible limit of 1.5 ppm for irrigation water (Table 84).

Table 84. Ranges of cations, anions, pH and EC of ground water samples of Prakasam district

Parameters	Range
pH	7.06-9.10
EC_e (dS/m)	0.45-11.13
CO_3 (meq/l)	0.00-5.00
HCO_3 (meq/l)	1.30-13.60
Cl (meq/l)	1.20-68.00
SO_4 (meq/l)	0.21-26.41
Ca (meq/l)	0.80-7.20
Mg (meq/l)	1.20-16.80
Na (meq/l)	1.00-108.2
F (ppm)	0.75-4.5
SAR (meq/l)	0.43-67.1
RSC (meq/l)	0.00-12.40

Response of Crops (Groundnut-Wheat) to Varying Levels of Salinity and Moisture under Sprinkler Irrigation - Bikaner

An experiment was conducted to evaluate the response of groundnut and wheat to irrigation water salinity and moisture levels. To create salinity gradient across the field, the field was divided into four parts along the width. Four sprinkler laterals, two with BAW (canal water) and other two with saline water (tube well water) were used to create three distinct zones *viz.* BAW, Mixed and Saline. The salinity of BAW and saline water was 0.26 and 3.90 dS/m. Thus, gradient of irrigation water salinity across the field ranged from 0.30 to 3.91 dS/m. The three nozzles size having 3.17, 4.13 and 5.1 mm diameter were used to create the moisture gradient along the field following the salinity gradient of irrigation water. Catch can method was used to measure amount of water applied at relative locations. Soil samples were collected at 2 m interval from the lateral. Crop cuttings were done at different locations from laterals from 4 m^2 area to correlate salinity/moisture gradient with yield of the crop.

The observed data revealed that application of water depth decreased with increase in distance from sprinkler line and decrease in nozzle discharge. In saline and BAW alone, the depth of irrigation varied from 2.68 to 6.12 cm and 2.72 to 6.19 cm, respectively. In case of mixed water the depth of water varied from 3.93 to 6.29 cm.

Pod yield was affected both by amount of water applied and salinity gradients. The data were subjected to regression analysis. The trend indicated that initially, up to 30 cm depth of irrigation water, there was linear increase in yield, but afterwards it followed quadratic trend and maximum of the curve for water depth was found to be around 70 cm (Fig. 21).

In the case of BAW, curve exhibited a platue zone at or around 60 cm of water applied with yield levels between 1.66 to 1.99 t/ha (Fig. 22). A maximum of the curve was found to be at 62 cm.

In the mixed zone, total depth of water applied ranged from 39.3 to 62.9 cm and grain yield varied from 0.24 to 1.54 t/ha. The equation for the mixed zone indicated that both salinity of irrigation water and total depth of water applied are responsible for yield variation. Assuming depth of water applied around 60 cm, the critical limit of 50% yield reduction was observed to be around 3.0 dS/m (Fig. 23).

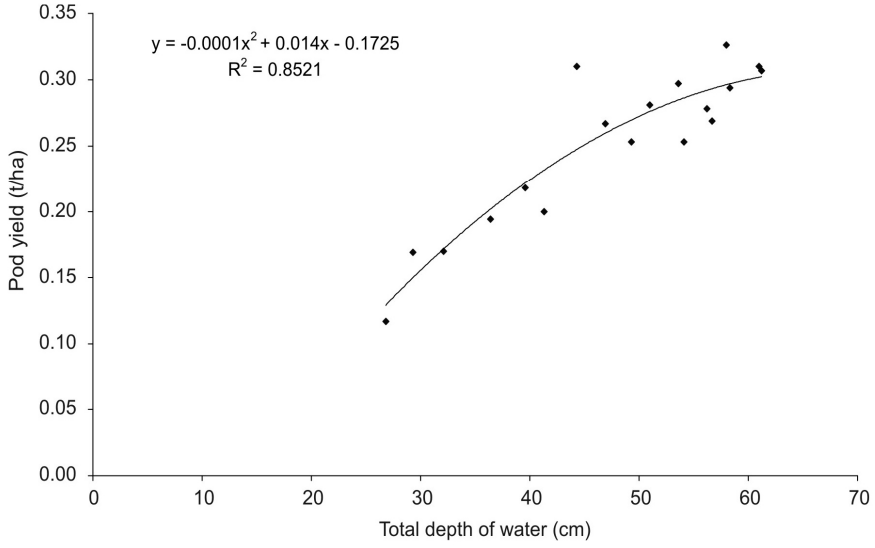


Fig. 21. Effect of irrigation water depth on pod yield of groundnut (saline)

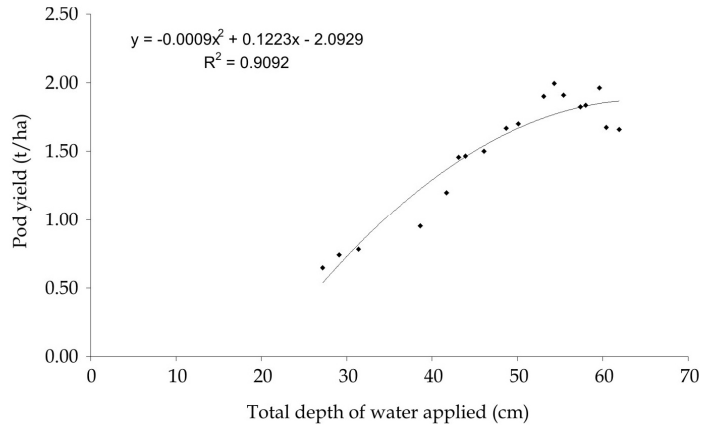


Fig. 22. Effect of irrigation water depth on pod yield of groundnut (BAW)

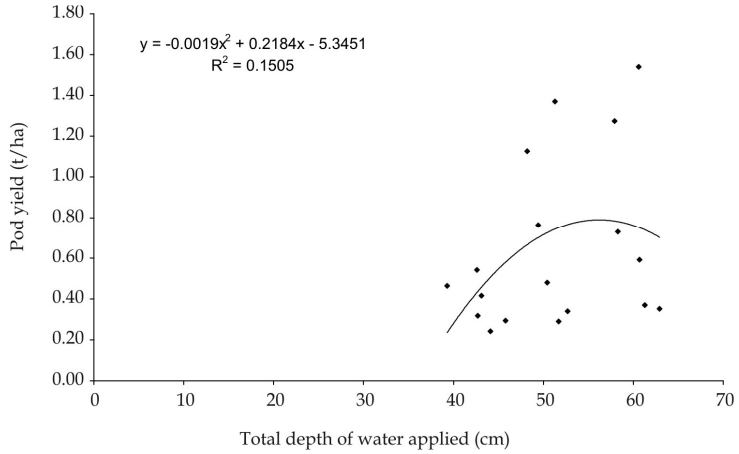


Fig. 23. Effect of irrigation water depth on pod yield of groundnut (Mixed)

Similar analysis of wheat was carried out for BAW (Fig. 24), mixed (Fig. 25) and saline (Fig 26) cases.

From the results it was inferred that total depth of water applied should be around 42 cm equally divided in seven irrigations when canal water is used under sprinkler irrigation system. Irrigation water salinity was found negatively correlated with yield, whereas, positive correlation was observed between yield and total depth of water applied.

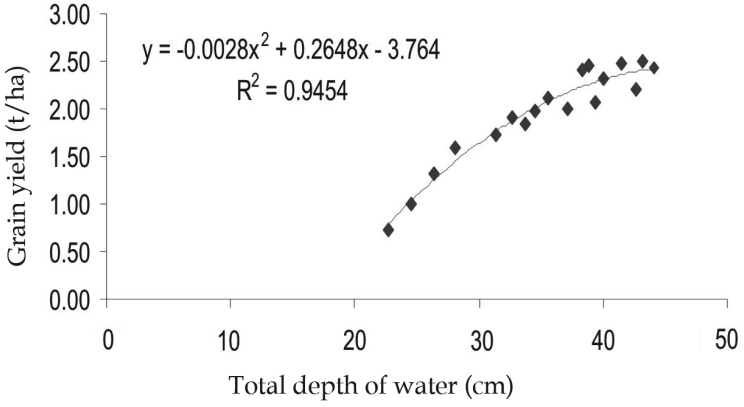


Fig. 24. Effect of irrigation water depth on grain yield of wheat (BAW)

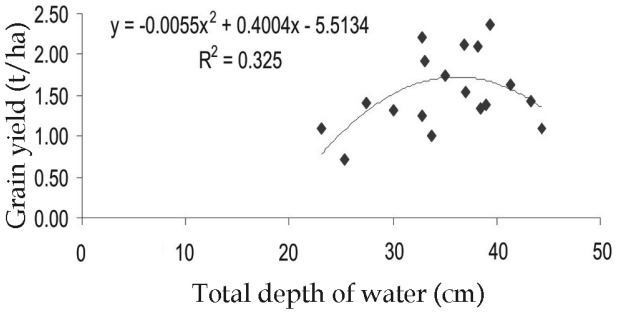


Fig 25. Effect of irrigation water depth on grain yield of wheat (Mixed)

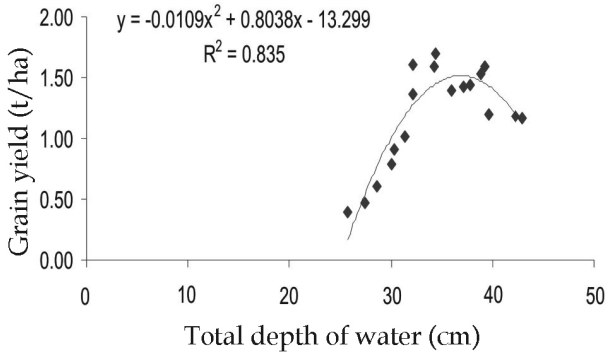


Fig. 26. Effect of irrigation water depth on grain yield of wheat (Saline)

To Optimize the Zinc Requirement of Wheat Crop Irrigated with Sodic Water - Hisar

To evaluate the zinc requirement of wheat crop under irrigation with sodic water, a study on the requirement of Zn was carried out in relation to different gypsum amendments (0, 25, 50, 75 and 100 per cent neutralization of RSC) at Village Bhurjat, District Mahendragarh from 2007-08. The experiment was conducted in plots of size 12.0 m x 12.0 m. The treatments consisted of five levels of gypsum application (0, 25, 50, 75 and 100 per cent neutralization of RSC) in the main plot and three levels of Zn (0, 25 and 50 kg/ha) in the sub-plot. All the treatments were replicated thrice. The initial pH of the soil was 9.6, 9.6, 9.4 and 8.9 respectively in 0-15, 15-30, 30-45 and 45-60 cm soil depth. The gypsum requirement of the soil was determined on the basis of exchangeable Na. The requisite amount of gypsum in various treatments on the soil and water basis was applied in a single dose before sowing of crop and mixed well in the soil. Irrigation schedule was based on the recommendations for the non-saline irrigated soils. The crops were irrigated with sodic water having average RSC 9.6 me/l and SAR 12.5 $(mmol/l)^{1/2}$. The ionic composition of irrigation water is given in Table 85. The water is bicarbonate type with 12.4 meq/l HCO_3^- content.

Table 85. Ionic composition and quality parameters of irrigation water

Ion/parameter	Values
CO_3 (meq/l)	Nil
HCO_3 (meq/l)	12.4
Ca (meq/l)	0.9
Mg (meq/l)	1.9
Na (meq/l)	15.8
Cl (meq/l)	1.8
EC (dS/m)	1.45
RSC_{iw} (meq/l)	9.6
SAR_{iw} $(mmol/l)^{1/2}$	12.5

During 2008-09, significantly higher yield was observed with increasing levels of gypsum as compared to control. The mean yield increased by 140, 235, 304 and 349 per cent, respectively, in G_{25}, G_{50}, G_{75} and G_{100} treatments as compared to control (Table 86). The application of Zn @ 25 and 50 kg/ha resulted in 10 and 16.9 per cent increase in yield, respectively, as compared to control.

Table 86. Grain yield (t/ha) of wheat in relation to Zn and gypsum application

Gypsum levels	Levels of Zn (kg/ha)			Mean
	Control	25	50	
G_0	0.64	0.90	1.14	0.89
G_{25}	1.87	2.18	2.38	2.14
G_{50}	2.78	3.05	3.16	2.99
G_{75}	3.42	3.63	3.78	3.61
G_{100}	3.81	4.02	4.19	4.00
Mean	2.50	2.75	2.93	
CD (5%)	Gypsum level (G): 0.178; Zn levels: 0.138; G x Zn: NS			

During 2009-10 also significantly higher yield was observed with increasing levels of gypsum as compared to control. The mean yield increased by 91.45, 145.31, 201.19 and 270.33 %, respectively, in G_{25}, G_{50}, G_{75} and G_{100} treatments as compared to control (Table 87). The application of Zn @ 25 and 50 kg/ha resulted in 16.2 and 27.5 % increase in yield, respectively, as compared to control.

Table 87. Grain yield (t/ha) of wheat in relation to Zn and gypsum application

Gypsum levels	Levels of Zn (kg/ha)			Mean
	Control	25	50	
G_0	0.79	1.09	1.39	1.09
G_{25}	1.53	2.23	2.49	2.08
G_{50}	2.44	2.68	2.88	2.67
G_{75}	3.05	3.24	3.54	3.28
G_{100}	3.67	4.09	4.33	4.03
Mean	2.30	2.67	2.93	
CD (5%)	Gypsum level (G): 0.130; Level of Zinc (Zn): 0.127; G x Zn: NS			

At the sowing, the maximum pH of the field was 9.50 (G_0) in 0-15 cm layer which decreased with increasing level of gypsum and the lowest pH of 8.53 was observed in G_{100}. At the wheat harvest in 0-15 cm layer, the pH in no gypsum treatment was 9.99 and 9.03 in G_{100} (Table 88).

Table 88. Depthwise pH of the soil under different treatments at sowing and harvesting of wheat

Soil depth (cm)	Levels of gypsum application					Mean
	G_0	G_{25}	G_{50}	G_{75}	G_{100}	
pH at the sowing						
0-15	9.50	9.18	9.12	8.81	8.53	9.03
15-30	9.70	9.29	9.21	9.12	9.01	9.27
30-45	9.69	9.38	9.29	9.18	9.11	9.33
45-60	9.62	9.49	9.35	9.38	9.21	9.41
Mean	9.63	9.34	9.24	9.12	8.97	
pH at the harvesting						
0-15	9.99	9.73	9.61	9.45	9.03	9.56
15-30	10.20	9.77	9.62	9.83	9.62	9.81
30-45	10.18	9.85	9.80	9.86	9.80	9.90
45-60	10.12	9.89	9.60	9.94	9.60	9.83
Mean	10.12	9.81	9.66	9.77	9.51	

Studies on the Long-Term Effect of Sewage Irrigation on Soils and Crops - Tiruchirapalli

The Trichy district city corporation sewage water is stored near Panchappur and it is stored in open aerated lagoons. After the BOD and COD are brought down to Polution Control Board guidelines, it is mixed in the Koraiyar river which and joins at Kulumayee Ammon Kovil. Then it is diverted into 2 water ways, viz., one is directed and mixed with the river Cauvey and another water way joins with Peruvalai canal and Pullambadi canal and ends at Vallavanthankottai tank. The later water course has been surveyed and the details are furnished as follow. Besides the survey, a field trial was also conducted at farmer's field at Karumandapam where the sewage water is used to irrigate rice crop (Fig. 27) during 2009 and 2010. During 2009 and 2010 soil and plant samples were collected and analysed for soil pH, EC and metal uptake (Pb, Cd, Ni) and the details are presented in Table 89, 90 and 91.

Table 89. Survey of sewage water along with water ways at different locations in Trichy district

S.No	Location Name	Geographical Coordinates	Water Sample	
			pH	EC
1	Panchappur (Starting point)	N 10° 45.714′ E 078°39.860′	7.13	1.43
2	Edamalaipattipudur (Second point)	N 10° 46.180′ E 078°39.755′	8.02	1.21
3	Karumandapam TRY-1(Fixed for field trial)	Water N 10° 47.729′ E 078°39.817′ Soil N10° 47.715′ E 078°39.817′	8.14 8.52	0.56 0.41
4	Kulumae Amman kovil	N10° 47.173′ E 078°39. 378′	7.80	0.40
5	Kulumae Amman kovil	N 10° 48.140′ E 078°39.938′	7.70	0.48
6	Tennur (behind Maruti hospital)	N 10° 48.603′ E 078°40.865′	8.02	0.45
7	Palakarai (Main Bridge, near Kaveri Theatre)	N 10° 45.584′ E 078°41.711′	8.15	0.33
8	Ariyamangalam	N 10° 45.771′ E 078°42.972′	7.80	0.58
9	Kattur Ellakkudi (Kattur post)	N 10° 48.064′ E 078°44.807′	7.99	0.54
10	Kattur Kailash Nagar	N 10° 47.679′ E 078°45.637′	8.21	0.69
11	Old Thiruvarembur (used as irrigation)	N 10° 47.505′ E 078°45.970′	8.25	0.94
12	Thiruvarembur SIT Stop	N 10° 47.052′ E 078°46.712′	7.99	0.62
13	Ehzil Nagar	N 10° 46.521′ E 078°48.565′	8.10	0.54
14	Ayampatti	N 10° 46.589′ E 078°49.430′	7.73	0.59
15	Valavanthankottai Area of the Tank:- 200ac	Water N 10° 45.516′ E 078°50.466′ Soil N 10° 45.483′ E 078°50.517′	8.12 7.28	0.49 0.29
16	Thirunedunkulam Area of the Tank:- 300ac Thirunedunkulam (Post)	N 10° 46.206′ E 078°51.147′	8.16	0.55

Table 90. Soil chemical properties and heavy metal content of sewage water irrigated field

	2009	2010
pH	6.7	8.2
EC (dS/m)	1.12	1.30
Available N (kg/ha)	290	310
Available P (kg/ha)	11	13
Available K (kg/ha)	220	190
Heavy metals (ppm)		
Pb	2.458	2.010
Cd	0.011	0.038
Ni	0.754	0.067

Table 91. Heavy metal content (ppm) in plants samples irrigated with sewage water

Heavy metals	2009			2010		
	Grain	Straw	Root	Grain	Straw	Root
Pb	0.011	0.007	0.007	0.007	0.008	0.007
Cd	BDL*	BDL*	BDL*	BDL*	BDL*	BDL*
Ni	0.002	0.002	0.001	0.002	0.001	0.002

**Below detection limit*

Fig. 27. Pumping of sewage water for irrigation

Tolerance of Vegetable Crops to Saline Irrigation under Drip and Surface System - Agra

An experiment was conducted to assess the tolerance of capsicum (winter) – okra (summer) crop rotation under drip and surface irrigation methods with different irrigation schedules. The treatments included a combination of saline irrigation waters (Canal, 4 and 8 dS/m) and irrigation schedule (IW/CPE ratio 0.75, 1.00 and 1.25). The fruit yield of capsicum and okra significantly decreased with increasing EC_{iw} levels in both drip and surface irrigation system during both the years (Table 92). The performance of capsicum was not satisfactory during 2008-09 due to mossace disease. During 2009-10 at EC_{iw} 4 and 8 (dS/m) the capsicum fruit yield reduced by 46.0 and 47.5% in drip and 39.8 and 53.1% in surface irrigation, respectively. The IW/CPE ratio was found non-significant under drip and surface irrigation.

The okra fruit yield reduced by 53.4 and 72.8% during 2008-09 and 53.4 and 78.4% during 2009-10 in EC_{iw} 4 and 8 (dS/m) over control. The okra yield increased significantly with increasing IW/CPE ratio in drip system only. In IW/CPE ratio 1.00 and 1.25, okra yield increased by 22.5 and 49.6% during 2008-09 and 19.4 and 80.5% during 2009-10 over IW/CPE ratio of 0.75. In surface irrigation method effect of IW/CPE ratio were found non-significant.

Table 92. Fruit yield (t/ha) of crops in drip and surface irrigation system under different treatments

Treatments	2008-09				2009-10			
	Drip irrigation		Surface irrigation		Drip irrigation		Surface irrigation	
	Capsicum*	Okra	Capsicum*	Okra	Capsicum	Okra	Capsicum	Okra
EC_{iw} levels (dS/m)								
Canal	0.48	10.18	0.46	8.41	19.49	12.34	12.51	12.23
4	0.32	4.74	0.29	3.36	12.64	5.74	7.52	2.52
8	0.25	2.77	0.20	0.01	10.22	2.66	6.19	0.00
CD at 5%	0.11	1.14	0.12	1.11	2.00	0.86	1.12	1.39
IW/CPE ratio								
0.75	0.36	4.75	0.37	4.23	14.50	4.94	9.06	5.12
1.00	0.35	5.82	0.32	3.82	14.63	6.88	8.81	5.07
1.25	0.33	7.11	0.26	3.72	13.23	8.92	8.36	4.52
CD (5%)	NS	0.86	NS	NS	NS	0.86	NS	NS
S x I	NS	NS	NS	NS	NS	NS	NS	NS

**Capsicum failed after two picking due to mossace disease*

The average total water use by okra varied from 34.8 to 70.6 cm in drip and 56.2 to 90.0 cm in surface irrigation system (Table 93). The water use efficiency decreased with increasing EC_{iw} levels and higher in drip than surface irrigation. In control and EC_{iw} 4 and 8 dS/m, the WUE was 203.7, 101.1 and 53.0 (kg/ha-cm) in drip and 138.8, 41.5 and 0.1 kg/ha-cm in surface irrigation system, respectively. The WUE was higher at IW/CPE ratio of 0.75 in both drip and surface irrigation as compared to other IW/CPE ratios.

Table 93. Water use (cm) and water use efficiency (kg/ha-cm) under different treatments in okra

Treatments	2009				2010				Average			
	Drip irrigation		Surface irrigation		Drip irrigation		Surface irrigation		Drip irrigation		Surface irrigation	
	WU	WUE	WU	WUE	WU	WUE	WU	WUE	WU	WUE	WU	WUE
EC_{iw} levels (dS/m)												
Canal	57.1	178.6	80.2	104.9	53.9	228.9	75.1	162.8	55.5	203.7	77.6	138.8
4	51.3	91.8	68.0	49.4	52.0	110.4	74.7	33.7	51.6	101.1	71.3	41.5
8	50.6	54.7	67.7	0.2	51.8	51.3	74.6	0.0	51.2	53.0	71.1	0.1
IW/CPE ratios												
0.75	30.5	155.7	55.1	76.8	39.2	126.1	58.4	87.6	34.8	140.9	56.2	82.2
1.00	50.2	115.9	71.9	53.1	53.0	129.8	75.1	67.5	51.6	122.8	73.5	60.3
1.25	77.1	92.2	89.2	41.7	64.2	138.9	90.9	49.7	70.6	115.5	90.0	45.7

WU = Water use; WUE = Water use efficiency

The EC_e in soil profile (0-60 cm) increased with increasing levels of EC_{iw} and IW/CPE ratio (Fig. 28). At harvesting of capsicum under drip irrigation, EC_e of the surface layer ranged from 2.55 to 3.0 dS/m in control, 4.55 to 5.25 in EC_{iw} 4 and 7.45 to 7.95 dS/m in EC_{iw} 8 at 5 to 25 cm distance from the plant. Corresponding value for the lower depth (30-60 cm) are 2.4 to 2.45, 3.4 to 3.35 and 3.95 to 4.15 dS/m, respectively. Similar trend was observed in IW/CPE ratio, EC_e was higher in IW/CPE ratio of 1.25 than 1.00 and 0.75. The same trend was also found in okra (Fig. 29).

The salinity build-up was higher in surface layer as compared to lower depth. At harvest of capsicum, average EC_e in surface layer (0-10 cm) were 3.3, 6.1 and 8.7 dS/m with canal, EC_{iw} 4 and 8, respectively. The EC_e in IW/CPE ratio was 6.8, 6.0 and 5.3 dS/m in 1.25, 1.00 and 0.75 IW/CPE ratio in surface layer. Corresponding, values for okra were 4.2, 3.0 and 24.0 with canal, EC_{iw} 4 and 8 dS/m and 15.0, 13.8 and 12.2 dS/m in IW/CPE ratio of 1.25, 1.00 and 0.75, respectively.

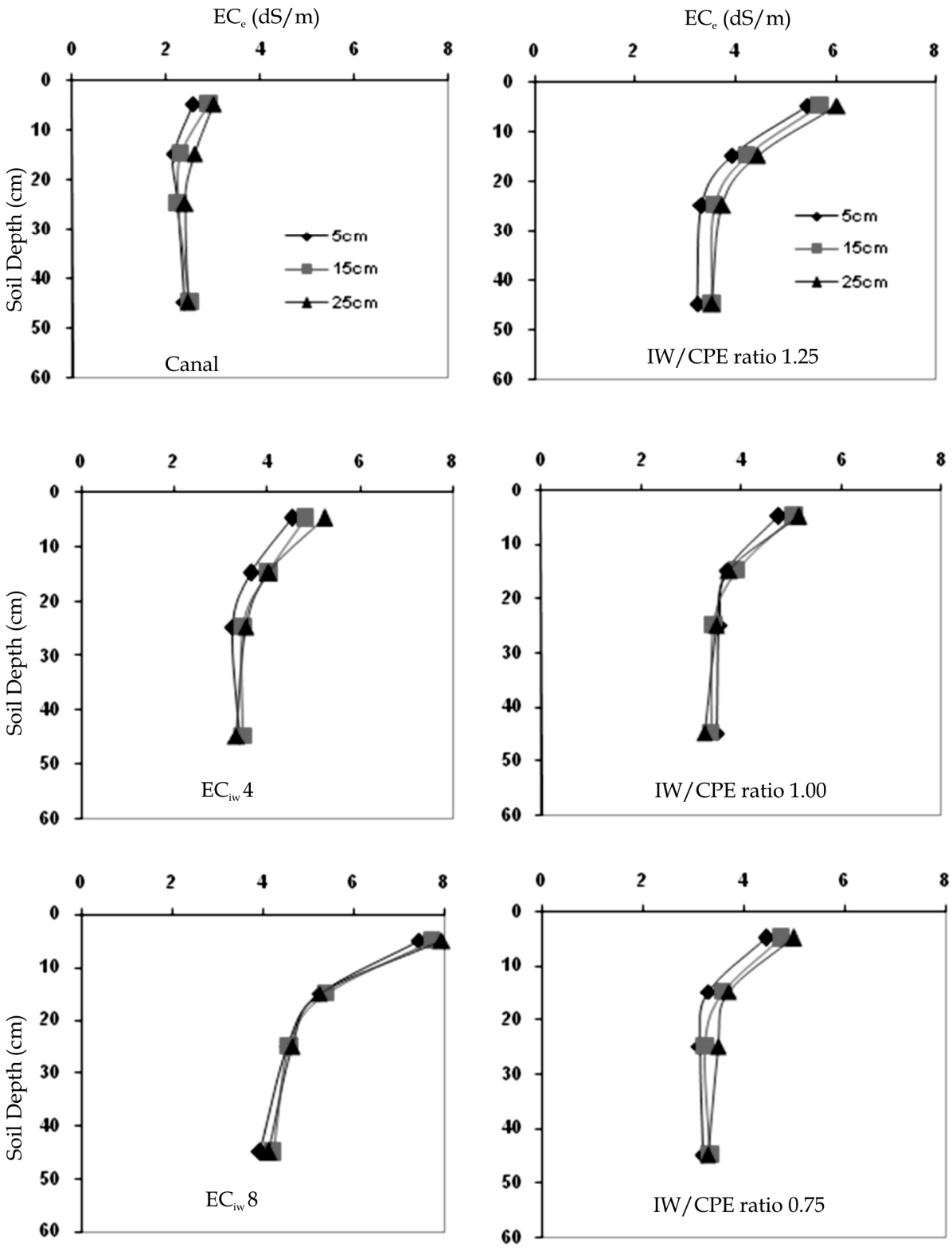


Fig. 28. EC_e in different EC_{iw} and IW/CPE ratios at harvest of capsicum in drip irrigation (Av. 2008-09 and 2009-10)

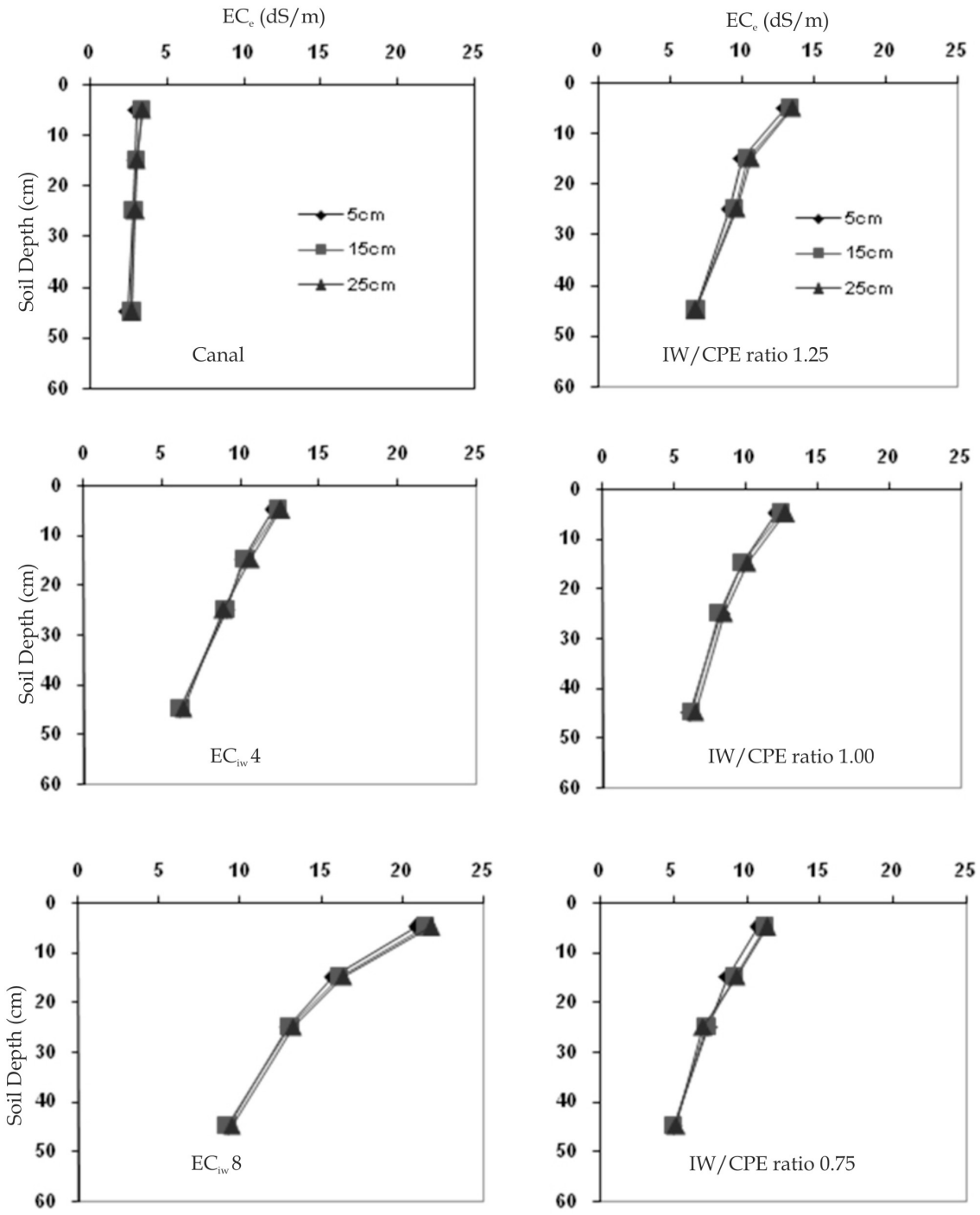


Fig. 29. EC_e in different EC_{iw} and IW/CPE ratios at harvest of okra in drip irrigation (Av. 2009 and 2010)

Drain Water Usage and Management Strategies of Nallamada Drain - Bapatla

During 2008-09, drain water samples were collected periodically from Nallamada drain from different locations viz., Kondapaturu, Pedanandipadu and Returu and also from Krishna Western Canal at Appapuram and analysed for EC, pH, CO_3, HCO_3, Cl, SO_4, Ca, Mg, Na and K. The data revealed that the EC of drain water upto the end of March, 2009 was <1.0 dS/m and fit for irrigation. The pH was below 8.0 upto December, 2008 and reached to >8.0 and below 9.0 from January, 2009 till March, 2009. SAR was within the safer limit of <10.0 and RSC was <2.50 meq/l during September, 2008 to March,

2009 (Table 94). From April onwards, the EC of drain water showed gradual increase and reached >3.0 dS/m.

Soil samples were also collected from three locations at Kondapaturu village and analysed for EC, pH and all ions and it was found that EC_e ranged from 0.70 to 1.36 dS/m, pH_s from 7.22 to 7.42 and SAR was within the safer limit of <10.0 (Table 95).

Table 94. EC, pH and SAR of Nallamada drain water at different locations comparing with Krishna Western Canal (Appapuram Canal) at periodical intervals during 2008-09

Date of sample collection	Name of location	EC_{iw} (dS/m)	pH	SAR $(mmole/l)^{1/2}$
26-09-2008				
	Kondapaturu (D)	0.85	7.03	2.10
	Pedanandipadu (D)	0.88	7.48	3.00
	Returu (D)	0.65	7.54	2.90
	Kommamuru (Appapuram canal)	0.49	7.40	1.33
04-12-2008				
	Kondapaturu (D)	0.76	7.97	2.70
	Pedanandipadu (D)	0.82	7.93	3.30
	Returu (D)	0.70	7.51	2.45
	Kommamuru (Appapuram canal)	0.61	7.97	0.13
06-01-2009				
	Kondapaturu (D)	0.83	8.13	0.50
	Pedanandipadu (D)	0.83	7.92	2.66
	Returu (D)	0.70	8.14	2.24
	Kommamuru (Appapuram canal)	0.59	8.43	2.05
16-01-2009				
	Kondapaturu (D)	0.89	8.32	3.30
	Pedanandipadu (D)	0.85	8.21	2.98
	Returu (D)	0.55	8.58	1.26
	Kommamuru (Appapuram canal)	0.53	8.30	1.20
10-02-2009				
	Kondapaturu (D)	0.84	8.25	0.58
	Pedanandipadu (D)	0.82	8.45	0.52
	Returu (D)	0.77	8.36	3.40
	Kommamuru (Appapuram canal)	0.61	8.00	1.98
24-02-2009				
	Kondapaturu (D)	0.90	8.36	3.40
	Pedanandipadu (D)	0.85	8.13	0.60
	Returu (D)	0.64	7.94	2.10
	Kommamuru (Appapuram canal)	0.59	8.00	1.90
12-03-2009				
	Kondapaturu (D)	0.72	8.60	1.24
	Pedanandipadu (D)	0.82	8.46	1.59
	Returu (D)	0.62	8.21	0.99
	Kommamuru (Appapuram canal)	0.58	8.51	1.35
24-03-2009				
	Kondapaturu (D)	0.90	8.59	2.53
	Pedanandipadu (D)	0.89	8.19	2.82
	Returu (D)	0.80	8.27	2.32
	Kommamuru (Appapuram canal)	0.58	8.45	1.49

Table 95. Initital soil analysis for EC_e, pH_s and SAR at Kondapaturu village near Naollamada drain

Name of farmer	EC_e (dS/m)	pH_s	SAR $(mmole/l)^{1/2}$
Potuneni Mohan Rao	0.7	7.22	2.1
Ramineni Tirupati Rao	0.72	7.42	2.5
Potuneni Mohan Rao	1.36	7.37	4.1

During 2009-10 collected basic data on existing lift irrigation schemes, drain layout from Pedanandipadu to sea coast and initiated survey under Pedanadipadu Lift Irrigation Scheme and collected information on crops grown and land holdings. The drain water samples were collected periodically.

Drain water samples collected during August, 2009 - May, 2010 revealed that the EC was around 1.08 to 1.92 dS/m during August, 2009 and again increased slowly from November, 2009 and maintained same level of EC up to March, 2010 and showed further rise from April 2010 and May 2010 (Table 96). This clearly showed that due to flow in irrigation chanels and rainfall during Southwest and Northeast monsoons, the salinity level of Nallamada drain water was within the safer limit of 2.0 dS/m and it was suitable for irrigating the crops. During this period the salintity of KW canal water is less than drain water and pH of drain water was 8.0 to 8.5.

Samples were also collected from Returu gauging station on daily basis during 2005-06 to 2008-09 (4 years) and analysed and quantified the drain water flows (Table 97 and Fig. 30). The results indicated that more than 175 TMC water flows through the gauging station and moved to sea during 2005-09. But by the method of moving average method only 157 TMC water observed to flow. As large quantities of good quality water flows in the drain during different periods, better planning could lead to higher agricultural productivity.

The performance of rice was tested in saline soils of Kondapaturu with leaching techniques using Nallamada drain water. With leaching, soil salinity reduced from 28.0 to 1 dS/m, 32 to 3.3 dS/m and 30 to 4.16 dS/m in farmers fields and the grain yields were 7.5 t/ha (BPT 2270), 3.5 t/ha (NLR145) and 5.63t/ha (BPT2270) respectively. It seems that BPT 2270 is having slightly higher salt tolerance than NLR 145 varitey.

Table 96. EC of Nallamada drain at different locations (2009-10)

Locations	EC (dS/m)								
	Aug, 2009	Oct, 2009	Nov, 2009	Dec, 2009	Jan, 2010	Feb, 2010	Mar, 2010	Apr, 2010	May, 2010
Pedanandipadu	1.92	0.87	0.80	0.79	0.78	0.86	0.88	0.70	2.18
Kondapaturu	1.20	0.21	0.84	0.77	0.77	0.81	0.89	0.82	1.65
Returu	1.92	0.20	0.69	0.71	0.78	0.85	0.78	0.91	1.20
Appikatala	1.44	0.82	0.48	0.82	0.79	0.85	0.92	1.33	1.63
K.B.palem	1.08	1.01	0.46	0.81	0.79	0.84	0.90	1.25	1.60
Appapuram Canal	0.53	0.11	0.48	0.71	0.62	0.63	0.61	0.68	0.61

Table 97. Nallamada drain flow during four years (2005-09)

Years	Yearly discharge (m^3)	Discharge (TMC)	Cumulative discharge (TMC)
2005-06	538549344	19.38	19.38
2006-07	1378965600	48.69	68.07
2007-08	1491723648	52.64	120.71
2008-09	1556647200	54.96	175.67

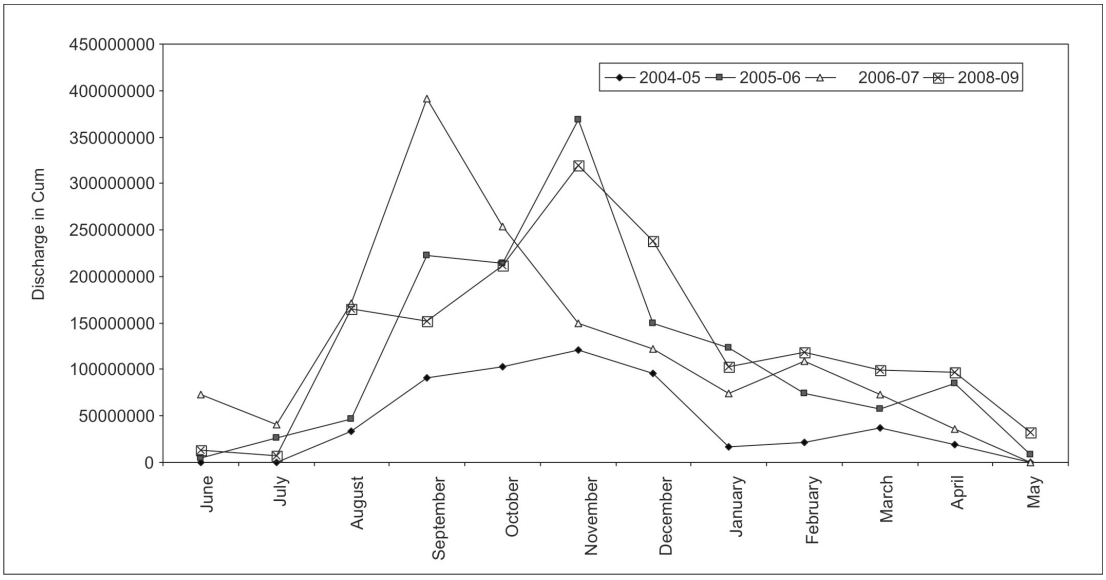


Fig. 30. Nallamada drain discharge at Gauging Station, Returu (2004-05 to 2008-09)

Organic Input Management Options with Saline Water Irrigation for Sustaining Productivity of High Value Crops-Karnal

Increasing shortage of good quality irrigation water in arid and semiarid regions of the country is forcing the farmers to utilize saline and alkali ground water for irrigation. To ensure their sustainable use in combination with organic inputs management to produce low water requiring high value crops such as oilseeds and spices, a field experiment was started during *kharif* 2008 at Bir Forest Experimental Farm, Hisar. Experiment was laid out in split plot design with two saline water irrigation (EC_{iw} <4, EC_{iw} >7) in main plots and 8 organic input management options in sub-plots.

Results of *kharif* 2008 showed that with organic inputs growth and yield attributes did not differ significantly yet higher seed yield of sesame (Table 98) was obtained as compared to 100 % inorganic and inorganic and organic (50+50) input applications. During 2009 seed yield was not significantly different with irrigation water salinity although numerically higher yield was recorded under high salinity water irrigation. It could be attributed to relatively higher RSC of the low salinity water. Perusal of the data on growth, yield attributes and yield of sesame under different treatments showed that plant height, plants/m row length, number of pods per plant differs significantly with saline water irrigation while 100 seed weight and seed yield reduced under high salinity water irrigation. Significant difference in plants/m row length, number of pods per plant and seed yield of sesame was observed with organic input applications as compared to inorganic fertilizer applications. Highest seed yield (0.28 t/ha) was observed under 100% recommended doses of organic inputs viz., farm yard manure + neem cake manure (Table 98).

Fennel crop results during 2008-09 showed that plant height, umbels per plant, 100 seed weight and seed yield differed non-significantly with saline water irrigation while umbellets per plant and seed weight per umbel reduced under high salinity water irrigation. Significant difference in plant height, umbellets per plant, seed weight per plant and seed yield of fennel was observed with organic input applications as compared to inorganic fertilizer applications. Highest seed yield (1.63 t/ha) was observed under 100% recommended doses of all three organic inputs viz., farm yard manure+vermicompost+non-edible neem cake manure. Perusal of the data on growth, yield attributes and yield of fennel under different treatments during second year of study showed that umbels per plant, umbellets per umbel, seed weight per umbel and 100 seed weight were not significantly different with saline water irrigation while plant height and seed yield reduced significantly under high salinity water irrigation. Significant difference in plant height of fennel was

observed with organic input applications. Highest seed yield (1.21 t/ha) was observed under 50% recommended doses of organic inputs viz., farm yard manure + vermicompost (Table 98). The recommendations would be framed at the completion of the project in due course of time.

Table 98. Seed yield of Sesame and Fennel under different treatments

Treatments	Sesame seed yield (t/ha)		Fennel seed yield (t/ha)	
	2008	2009	2008-09	2009-10
EC_{iw} <4	0.38	0.29	1.50	1.26
EC_{iw} >7	0.40	0.10	1.40	0.85
CD (5%)	NS	NS	NS	0.41
T 1	0.25	0.11	1.37	0.97
T 2	0.30	0.15	1.17	1.01
T 3	0.49	0.18	1.44	1.21
T 4	0.40	0.17	1.34	1.11
T 5	0.46	0.16	1.55	1.17
T 6	0.43	0.21	1.44	0.88
T 7	0.39	0.28	1.60	1.05
T 8	0.40	0.25	1.63	1.03
CD (5%)	0.08	0.10	0.31	NS

T_1:100% Inorganic fertilizer T_2: Inorganic + organic inputs (50% each), T_3: FYM+ Vermicompost (50:50), T_4: FYM+ Non-edible oilcake manure (50:50), T_5: FYM+ Vermicompost+Non-edible neem cake manure (33% each), T_6: FYM +Vermicompost (100: 100), T_7: FYM+Non-edible neem cake manure (100:100), T_8: FYM+Vermicompost+Non-edible neem cake manure (66.6% each).

B. MANAGEMENT OF SALT AFFECTED SOILS

- Delineation and Mapping of Salt Affected Soils
- Reclamation of Sodic Vertisols in Conjunction with Soil and Water Conservation Practices under Rainfed Condition (Indore)
- Investigations on Micro Irrigation Requirements of Vegetables for Saline Soils (Gangawati)
- Reclamation of Abandoned Aqua Ponds (Bapatla)
- Evaluation of Zero Tillage System under Semi-Reclaimed Sodic Soil (Kanpur)
- Effect of Set Furrow method of Gypsum Application and Textural Modification on Soil Reclamation and Crop Performance (Indore)
- Influence of Spent Wash and Spent Wash Vermi-Compost on Reclamation of Sodic Soils (Indore)
- Response of Crops to Chemical and Organic Amendments in Alkali Vertisols (Gangawati)
- Land and Rain Water Management Strategies for Cultivation in Rainfed Sodic Soils (Gangawati)
- Effect of Long-Term Application of Organic/Green Manures in Sodic Vertisols (Indore)
- Studies on Crop Performance after Tree Harvesting in Alkali Soil Environment (Indore)
- Effect of Switching Over to Upland Cropping Sequence on Re-Sodification and Sustainability of Crop Yield in Reclaimed Sodic Soil under Constrained Water Supply Conditions (Kanpur)
- Monitoring and Evaluation of Large Scale Drainage Projects in the State of Haryana (Karnal)
- Subsurface Drainage for Heavy Soils of Maharashtra and Karnataka under Public Private Partnership Mode (Karnal)
- Drainage Investigations, development of Design Criteria, Design and Installation of Subsurface Drainage Systems and Monitoring for controal of Water logging and Salinity in Heavy Textured Soils of Appikatla, Krishna Western Delta (Bapatla)
- Monitoring Salinity Hazards in Vegetable Crops under Drip Fertigation with Marginally Saline Water in Vertisols (Indore)
- Effect of Doses and Frequency of Gypsum Application on Soil Properties and Crop Performance in Sodic Soil on Long-Term Basis (Indore)
- Efficacy of Phosphogypsum as an Amendment for Alkali Soil (Kanpur)
- Effect of Management Practices on Resodification of Reclaimed Sodic Lands at Benchmark Sites (Kanpur)
- Evaluation of Integrated Resource Conservation Technology for Rice-Wheat Cropping System under Reclaimed Sodic Soil (Kanpur)

Delineation and Mapping of Salt Affected Soils

Bapatala: Nellore, Guntur and Parkasham districts

Delineation and mapping of salt affected soils was continued. During 2009-10 survey of Nellore, Guntur, Prakasam, Krishna and West Godavari districts was completed.

Nellore district

In Nellore district, 157 soil samples were collected and analysed. The analytical data indicated that the soil EC_e values ranged from 0.02 to 101.7 dS/m while the pH_s values ranged from 5.5 to 10.7.

Guntur district

In Guntur district, 220 soil samples were collected and analysed. The analytical data indicated that the soil EC_e values ranged from 0.58 to 100.0 dS/m while the pH_s values varied from 5.1 to 8.84. Out of 220 soil samples analysed, 18.2 per cent were saline soils, 0.9 per cent were alkali soils and 0.5 per cent were saline–alkali soils and the remaining 80.4 per cent were good/normal soils.

Prakasam district

In Prakasam district, 192 soil samples were collected and analysed. The analytical data indicated that the soil EC_e values ranged from 0.03 to 66.0 dS/m while the pH_s values ranged from 6.12 to 9.12. Out of 192 soil samples analysed, 20.3 per cent were saline soils, 3.7 per cent were alkali soils, 2.1 per cent saline-alkali soils and the remaining 73.9 per cent were good/normal soils. The EC, pH and ESP maps of Ongole division were prepared (Fig. 31, Fig. 32, and Fig. 33).

Kanpur-Sharda Sahayak Canal

The benchmark sites of Sharda Sahayak Canal area in the district were demarcated on both sides of the canal. Soil samples were collected from 0-20, 20-40,40-60,60-90,90-120 and 120-150 cm depth at an interval of 100, 500, 1000, 1500, and 2000 m distance on both sides during pre and post monsoon period.

The soils are clay loam at the surface becoming heavier in texture towards the lower depths in Maharajganj Tehsil. These soils are very hard and compact when dry and become sticky when moist. The analytical results of soils samples showed wide variation in cationic and anionic composition at different depth (0-20 to 120-150 cm). At surface the pH value ranged from 10.1 to 8.4, EC_e 3.3 to 2.0 dS/m, Carbonate 13.6 to nil, bicarbonate 27.5 to 10.6, chloride 7.6 to 1.6 and sulphate from 6.9 me/l to traces. Among the anions, bicarbonate was dominant followed by carbonate and chloride, which were unevenly distributed in the soil profile. Among the cations, the sodium was dominant till 60 cm and after 60 cm depth calcium plus magnesium were dominant. The values of anion and cations concentration are given in Table 99 as an example. Mean data on A (left bank) and B (right bank) sides of the canal are given in Table 100 and 101 and depicted in Fig. 34. Some fields were waterlogged and water samples from these fields were also collected for analysis. The performance of crop was almost poor in most of the fields.

The soils were neutral in reaction with the exception of surface layer and are poor in organic matter content. Moderate illuviation of sesquioxides was visible at lower depth. At some of the places, the soils were fertile and are typically suited to paddy and other water loving crops in *kharif* season. In some places the kankar pan was also observed at a depth of 60 to 90 cm. The soils of village Shivdeenkhera were almost waterlogged. Plant roots were found at the surface, organic carbon was higher in the surface layer and decreased with depth.

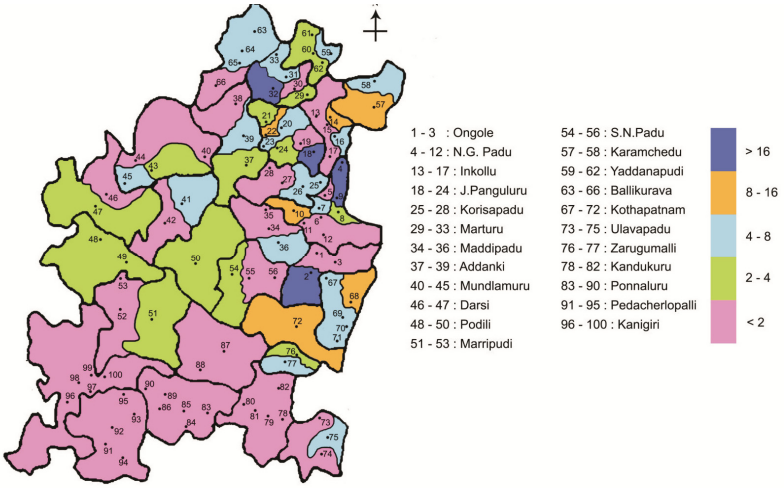


Fig. 31. EC_e status of soils of Ongole division

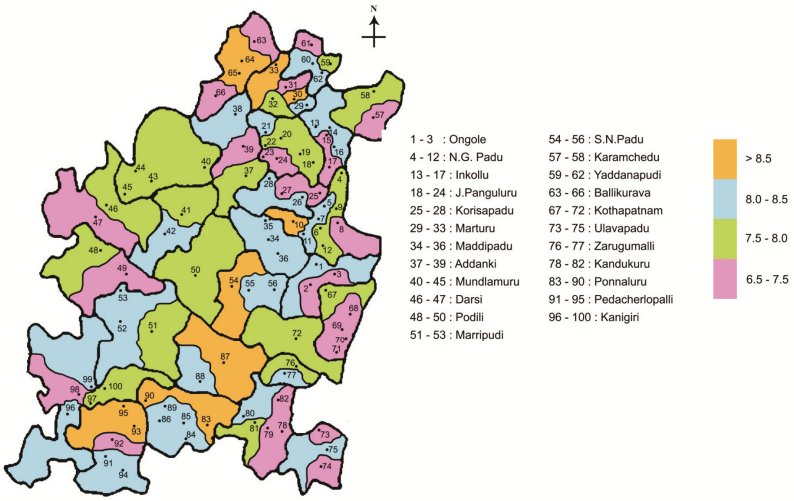


Fig. 32. pH status of soils of Ongole division

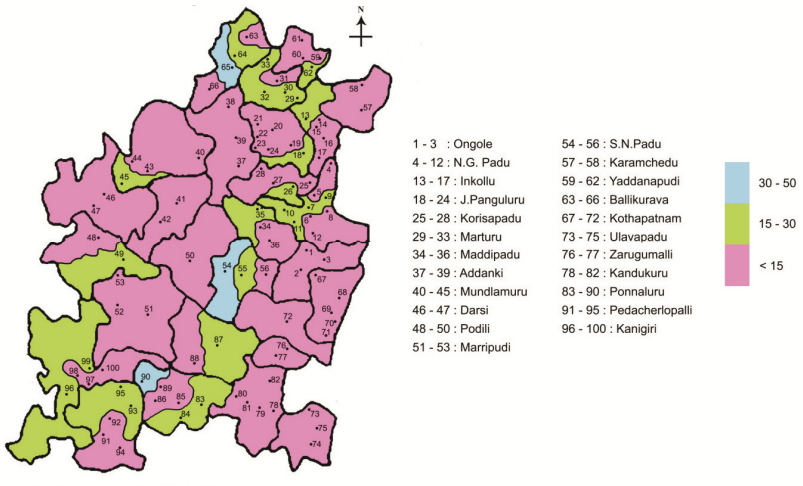


Fig. 33. ESP status of soils of Ongole division

Table 99. Analysis of Soil Samples in the command area of Sharda Sahayak Canal

S.N.	Distance from canal (m)	Depth, cm	pH	EC_e (dS/m)	CO_3 (meq/l)	HCO_3 (meq/l)	Cl (meq/l)	SO_4 (meq/l)	Ca+Mg (meq/l)	Na (meq/l)
1	100	0-20	9.5	3.3	8.3	17.1	6.8	1.6	11.5	22.3
2	100	20-40	9.3	3.3	7.5	19.9	4.8	1.3	13.9	20.0
3	100	40-60	9.0	3.3	5.4	22.9	4.6	0.6	16.7	17.3
4	100	60-90	8.9	3.1	3.3	24.0	3.5	0.5	17.9	12.8
5	100	90-120	8.7	3.0	3.8	24.2	2.9	Tr.	21.8	8.2
6	100	120-150	8.6	3.2	3.0	27.5	1.6	Tr.	26.3	5.3
7	500	0-20	9.0	2.4	4.6	12.2	5.9	1.5	8.6	13.0
8	500	20-40	8.9	2.4	4.8	12.7	4.8	1.6	9.8	11.6
9	500	40-60	8.8	2.3	3.3	13.0	3.1	Tr.	10.2	12.7
10	500	60-90	8.7	2.3	2.6	17.6	2.4	Tr.	9.3	9.2
11	500	90-120	8.5	2.1	2.3	16.8	2.1	Tr.	10.1	12.4
12	500	120-150	8.4	2.1	1.0	11.4	1.7	0.3	7.8	10.6
13	1000	0-20	9.8	3.4	6.9	14.0	6.9	6.9	11.6	23.1
14	1000	20-40	9.7	3.2	6.5	11.8	6.6	5.1	13.8	19.2
15	1000	40-60	9.6	3.0	5.8	14.9	5.1	4.2	14.1	15.8
16	1000	60-90	9.5	2.5	3.0	12.9	4.6	3.0	15.4	10.1
17	1000	90-120	9.4	2.5	1.8	19.0	2.3	1.6	16.3	9.2
18	1000	120-150	9.3	2.1	1.6	17.6	1.8	Tr.	13.7	8.2
19	1500	0-20	9.9	2.9	6.9	10.6	7.6	3.6	13.8	15.3
20	1500	20-40	9.8	2.9	7.6	13.3	6.8	2.0	13.9	15.3
21	1500	40-60	9.7	2.9	4.6	16.1	6.1	2.0	17.4	11.5
22	1500	60-90	9.6	2.8	3.0	20.3	3.0	1.6	18.5	10.4
23	1500	90-120	9.6	2.8	2.5	22.8	2.8	Tr.	20.2	7.8
24	1500	120-150	9.4	2.5	0.3	24.0	1.6	Tr.	20.4	4.9
25	2000	0-20	9.9	3.3	11.6	17.6	3.8	Tr.	11.0	23.6
26	2000	20-40	9.8	3.2	7.9	19.6	3.0	0.5	15.8	17.2
27	2000	40-60	8.7	3.2	7.4	21.8	2.3	0.8	16.6	15.7
28	2000	60-90	9.5	3.2	3.3	25.6	2.6	Tr.	19.6	11.6
29	2000	90-120	9.3	3.1	4.5	25.1	Tr.	Tr.	23.8	6.6
30	2000	120-150	9.2	3.1	3.0	26.2	Tr.	Tr.	29.6	2.1

Table 100. Mean data analysis of soil samples collected from A side (left bank) of the canal

Depth (cm)	pH	EC_e (dS/m)	CO_3 (meq/l)	HCO_3 (meq/l)	Cl (meq/l)	SO_4 (meq/l)	Ca+Mg (meq/l)	Na (meq/l)
0-20	9.6	3.4	7.3	16.1	7.0	4.2	9.5	24.8
20-40	9.5	3.3	6.0	17.8	5.8	3.4	11.0	21.9
40-60	9.3	3.1	4.6	20.0	4.4	2.8	13.3	17.9
60-90	9.2	2.9	3.4	21.5	3.0	2.4	15.5	14.0
90-120	9.1	2.8	2.4	22.9	1.9	1.7	17.8	10.3
120-150	8.9	2.7	1.7	23.8	1.3	1.4	19.4	7.5

Table 101. Mean data analyses of soil samples collected from B side (right bank) of the canal

Depth (cm)	pH	EC_e (dS/m)	CO_3 (meq/l)	HCO_3 (meq/l)	Cl (meq/l)	SO_4 (meq/l)	Ca+Mg (meq/l)	Na (meq/l)
0-20	9.5	3.4	5.6	14.5	9.5	5.0	11.2	23.0
20-40	9.3	3.3	4.5	17.0	7.8	4.0	12.6	19.9
40-60	9.2	3.1	3.7	19.3	5.9	3.0	15.1	16.2
60-90	9.0	3.0	2.8	21.4	4.2	2.2	17.7	12.3
90-120	8.8	2.9	2.3	22.8	3.2	1.7	19.3	9.2
120-150	8.7	2.7	1.8	23.1	2.1	1.4	20.9	5.9

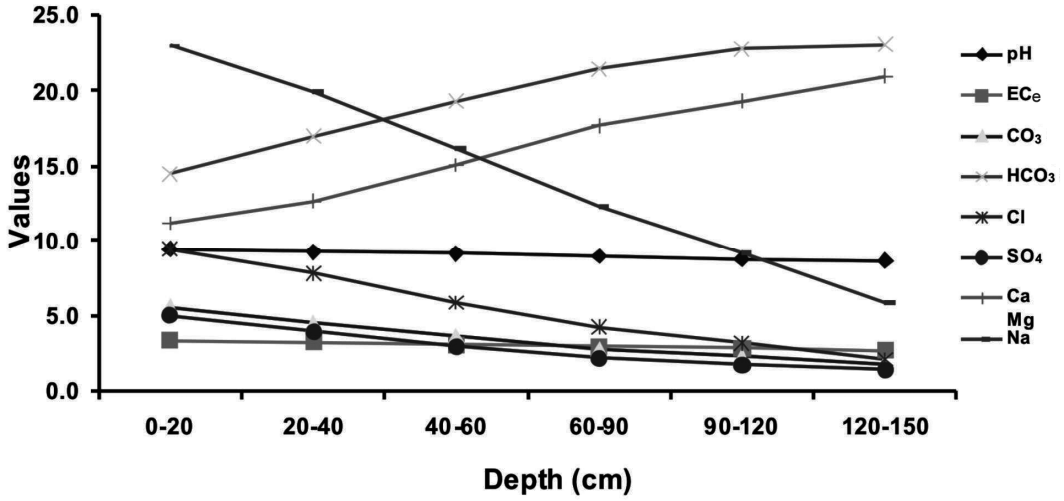


Fig. 34. Variation of chemical parameters with depth (right bank of Sharda Sahayak Canal)

Reclamation of Sodic Vertisols in Conjunction with Soil and Water Conservation Practices under Rain fed Conditions-Indore

The experiment is being carried out on a sodic Vertisol at Barwaha (Madhya Pradesh) having initial soil ESP of 60 to 70. For efficient reclamation, the land was amended first up to plough layer (0-20 cm) with gypsum @ 100% GR in the first year before the onset of monsoon. After allowing dissolution of gypsum during rainy season, the raised and sunken beds of different dimensions were prepared in the year 1994 by shifting amended soil of the plough layer of sunken beds over to raise beds to achieve 40 cm height difference. The exposed soil layer beneath 20 cm depth of sunken bed was treated again with gypsum @ 100% GR to lower down soil ESP. The different ratios (1:2, 1:1, 3:2 and 2:1) of raised to sunken beds were achieved with constant sunken bed width of 7.5 m in the year 2002. To get rid off the salt accumulated during summer on the soil surface, the first rain water conserved in sunken beds were disposed off. The paddy was cultivated in sunken beds. On raised beds cotton was sown with standard package of practices. To ensure good germination of cotton 50 g gypsum + 50 g FYM per hill was applied at the time of basal application of fertilizer before sowing.

The agro-climatic data revealed that enough precipitation was received in the beginning of monsoon so sufficient moisture was stored in the sunken and raised beds before transplanting/sowing of paddy and cotton crops, respectively. It helped in good germination. The restricted water transmission properties of the soil helped in storing the water in sunken bed through runoff from raised beds. The rainfall received up to September/ October was 419 and 624 mm during the year 2008-09 and 2009-10 respectively. The sunken beds had enough water for transplantation of paddy.

The chemical properties of soil (Table 102) revealed that the salts accumulated in surface soils decreased with depth. Soil ESP was lower in top layer and increased with depth. The soil ESP was higher on raised beds as compared to sunken beds. There was reduction in soil pH_s and EC_e (Table 103) after continuous cropping under raised and sunken bed system. The reduction in EC_e of soil also indicates sufficient leaching/ flushing of salt is continuing under this system. However, there was some rebuilding of ESP and deterioration in soil properties on raised beds and even in sunken beds either due to complete exhaust of gypsum after a period of over 8/9 years of its application or displacement of soils during preparation of beds of various ratios. ESP build-up in latter years showed that in the absence of gypsum application the biological efficiency of reclamation with the help of paddy crop and rainwater is minimal in black alkali soils.

Table 102. Soil chemical properties in sunken and raised beds before start of the experiment

Soil depth (cm)	4.5 m				6.0 m				7.5 m			
	Raised bed		Sunken bed		Raised bed		Sunken bed		Raised bed		Sunken bed	
	EC_e	ESP	EC_e	ESP	EC_e	ESP	EC_e	ESP	EC_e	ESP	EC_e	ESP
0-15	3.5	35.0	4.5	38.0	4.3	36.0	4.8	40.0	4.0	37.0	5.0	41.0
15-30	3.3	36.0	2.9	44.0	3.5	39.0	3.5	45.0	3.8	39.0	2.4	48.0
30-45	1.7	38.0	3.4	46.0	2.0	40.0	3.5	48.0	2.8	42.0	3.1	50.0
45-60	2.6	43.0	1.8	51.0	2.8	45.0	2.0	52.0	2.6	49.0	2.5	52.0
60-90	2.2	46.0	2.5	52.0	2.0	48.0	2.0	52.0	2.1	50.0	2.2	52.0

Table 103. Changes in average chemical properties in raised and sunken bed system

Depth (cm)	pH			EC_e (dS/m)			ESP		
	Initial	Raised	Sunken	Initial	Raised	Sunken	Initial	Raised	Sunken
					2008-09				
0-15	8.2	8.2	8.1	3.5	1.7	1.7	37.0	49.6	40.3
15-30	8.2	8.2	8.2	3.3	1.7	1.8	41.0	50.8	41.4
30-45	8.3	8.3	8.3	2.7	2.0	2.1	48.0	52.4	48.5
45-60	8.3	8.2	8.3	2.6	2.1	2.4	50.0	55.5	53.6
60-90	8.3	8.3	8.3	2.2	2.4	2.6	52.0	55.4	54.5
					2009-10				
0-15	8.2	8.2	8.1	3.5	1.8	1.6	37.0	49.8	41.1
15-30	8.2	8.3	8.1	3.3	1.9	1.7	41.0	51.4	41.9
30-45	8.3	8.4	8.3	2.7	2.3	1.9	48.0	53.6	49.5
45-60	8.3	8.3	8.4	2.6	2.4	2.2	50.0	55.9	53.6
60-90	8.3	8.3	8.3	2.2	2.4	2.4	52.0	56.4	54.5

The seed cotton yield and paddy grain yield recorded for different ratios are presented in Table 104. The paddy grain yield in general was satisfactory due to the reason that introduction of water harvesting and recycling technology could provide 2 to 3 irrigations of 7 cm each to paddy crop during temporary stress. The highest grain yield of paddy was recorded when the ratio of raised to sunken bed was 2:1 and it decreased with decreasing ratio of raised to sunken bed. The difference in yield between 3:2 and 2:1 ratio was non significant. The average yield of paddy was 2.04 and 2.10 t/ha during the year 2008-09 and 2009-10 respectively. Maximum seed cotton yield (1.24 and 1.70 t/ha) was recorded in case of raised to sunken bed ratio 1:2 whereas, the minimum seed cotton yield was observed under 2:1 ratio. The average seed cotton yield during the year 2008-09 and 2009-10 was 1.39 and 1.05 t/ha respectively.

Table 104. Paddy and seed cotton yield (t/ha) from various raised: sunken bed ratio

Crop	Ratio of raised to sunken bed				
	1:2	1:1	3:2	2:1	Mean
Paddy (sunken bed) (2008-09)	1.70	1.99	2.12	2.28	2.04
Paddy (sunken bed) (2009-10)	1.79	2.09	2.18	2.36	2.10
Cotton (raised bed) (2008-09)	1.67	1.41	1.29	1.21	1.39
Cotton (raised bed) (2009-10)	1.24	1.13	0.99	0.86	1.05

Investigations on Micro Irrigation for Vegetables in Saline Soils – Gangawati

The beetroot and cabbage crops were grown during 2008-09 and 2009-10 respectively. The results indicated that irrespective of salinity levels, significantly higher beet yield of 17.9 t/ha was recorded when the crop was drip irrigated with ET level of 1.2 followed by 1.4 ET (16.7 t/ha), 1.0 ET (16.5 t/ha), 0.8 ET (15.2 t/ha), surface irrigation at 1.2 ET (14.6 t/ha), drip irrigation at 0.6 ET (14.3 t/ha), surface irrigation at 1.0 ET (13.6 t/ha), and least (12.5 t/ha) when the crop was irrigated with surface irrigation at 0.8 ET level (Table 105).

Table 105. Yield of beetroot and cabbage under different treatments

Irrigation levels	Beetroot yield (t/ha)				Cabbage yield (t/ha)			
	Salinity levels				Salinity levels			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
I_1	17.8	15.3	9.8	14.3	15.5	11.3	7.2	11.3
I_2	18.8	16.2	10.6	15.2	17.1	13.2	9.0	13.1
I_3	20.0	17.4	11.9	16.5	18.2	14.2	9.6	14.0
I_4	21.2	19.0	13.4	17.9	18.8	15.7	11.0	15.1
I_5	20.3	17.7	12.2	16.7	18.6	15.2	10.8	14.8
I_6	16.1	13.8	7.7	12.5	13.0	9.2	6.9	9.7
I_7	17.0	14.7	9.3	13.6	14.6	10.0	7.6	10.8
I_8	18.0	15.7	10.4	14.6	16.4	11.6	8.7	12.2
Mean	18.6	16.2	10.7		16.5	12.5	8.8	
	CD (5%)					CD (5%)		
I	0.77				I	0.54		
S	0.29				S	0.47		
I x S	NS				I x S	NS		

S_1 – EC <4 dS/m; S_2 – EC 4-8 dS/m; S_3 – EC 8-12 dS/m; I_1 - Drip Irrigation at 0.6 ET; I_2 - Drip Irrigation at 0.8 ET; I_3 - Drip Irrigation at 1.0 ET; I_4 - Drip Irrigation at 1.2 ET; I_5 - Drip Irrigation at 1.4 ET; I_6 - surface Irrigation at 0.8 ET; I_7 - surface Irrigation at 1.0 ET; I_8 - surface Irrigation at 1.2 ET

Among salinity levels, significantly higher yield (18.6 t/ha) was observed in the EC_e <4 dS/m block followed by EC_e 4-8 dS/m (16.2 t/ha) and significantly least (10.7 t/ha) in case of EC_e 8-12 dS/m. However, the interaction effect due to irrigation levels and soil salinity levels remained non-significant.

Irrespective of salinity levels, significantly higher cabbage yield of 15.1 t/ha was recorded when the crop was drip irrigated with ET level of 1.2 followed by 1.4 ET (14.8 t/ha), 1.0 ET (14.0 t/ha), drip irrigation at 0.8 ET (13.1 t/ha), surface irrigation at 1.2 ET (12.2 t/ha), drip irrigation at 0.6 ET (11.3 t/ha), surface irrigation at 1.0 ET (10.8 t/ha), and least (9.7 t/ha) when the crop was irrigated with surface irrigation at 0.8 ET level

Among salinity levels, significantly higher yield (16.5 t/ha) was observed in the EC_e <4 dS/m followed by EC_e 4-8 dS/m (12.5 t/ha) and least (8.8 t/ha) in case of EC_e 8-12 dS/m.

Soil salinity was marginally higher in the treatments where the crop was irrigated with 0.8 ET under surface irrigation and relatively lower in case where the crop was drip irrigated with ET level of 1.4 as compared to other treatments.

Reclamation of Abandoned Aqua Ponds - Bapatla

During 2008-2009, aqua ponds were selected at 14 farmer's field and were leveled followed by cultivating and making open drainage channel for leaching of the salts. *Dhaincha* was sown and ploughed *in-situ* at 50% flowering. Rice varieties (NLR 145, CSR-23 and BPT-5204) were grown. The results showed that the initial soil EC_e of abandoned aqua lands ranged from 2.70 to 106.0 dS/m and final analysis indicated that EC_e ranged from 2.0 to 77.0 dS/m. $ZnSO_4$ was applied @ 50 kg/ha as basal and NPK @ 180 kg N- 40 kg P_2O_5 – 40 kg K_2O /ha were applied. The EC_{iw} was 2.1 dS/m. The grain yields obtained in the range of 0.13 to 6.0 t/ha and in some locations the establishment of rice was poor due to very high salinity (Table 106).

Table 106. Changes in soil EC_e, pH and grain yield of rice in abandoned aqua ponds

Name of the farmer	Area (acre)	EC_e (dS/m)		pH		Grain yield (t/ha)
		Initial	Final	Initial	Final	
Naidu Nagendram	0.5	65.0	5.8	7.62	8.04	1.88
Naidu C. Venkateswarlu	0.5	76.0	2.8	7.62	7.76	5.75
Seru Nagaswararao	1.0	18.7	6.1	7.49	7.34	4.50
Naidu Gandhi	0.5	106.0	9.3	7.31	7.53	0.13
Naidu Koteswarao	0.5	97.0	5.0	7.57	7.23	5.63
N . Pedavenkateswarlu	0.5	88.0	32.0	7.51	7.08	**
N . Venkatasubbiah	0.5	77.0	2.4	7.49	8.27	5.50
Naidu Arjuna Rao	0.5	105.0	48.0	7.46	7.82	**
V.Veeraraghavaiah	2.0	59.0	37.0	7.62	7.71	**
Badugu Balaramiah	1.0	69.0	64.0	7.58	7.09	**
Badugu Krishnamurthy	0.5	89.0	38.0	7.36	7.07	**
Kanna.Veeraraju	2.5	31.0	2.7	7.64	7.95	5.70
Chapala.Sudhakar	1.0	2.7	2.0	8.61	7.74	6.00
Chippala.Srinivasarao	3.0	82.0	2.1	7.49	7.47	5.95

** *Poor establishment*

During 2009-10 the data revealed that the initial EC_e ranged from 4.85 to 23.36 dS/m and pH from 7.6 to 8.5 at five locations belonging to 5 farmers from 4 different villages, following similar approach of on-farm land development, rice varieties viz., MTU-2716, BPT-5204 and NLR-145 was grown and $ZnSO_4$ was applied basally @50 kg/ha and N-P_2O_5 –K_2O applied @180-40-40 kg/ha. The final soil analysis indicated that the EC_e ranged from 2.5 to 14.51 dS/m, pH_s from 7.83 to 8.76. The rice grain yields ranged from 3.8 to 5.6 t/ha (Table 107).

Table 107. Initial and final soils analysis for pH_s, EC_e and rice yield (t/ha)

Name of the farmer	Area (acre)	EC_e		pH_s		Rice variety	Yield (t/ha)	Source of irrigation
		Initial	Final	Initial	Final			
A. DasaradaRami Reddy	1.0	4.85	2.5	8.5	8.4	MTU-2716	5.6	K.W. canal water
Muppala Sambasivarao	1.50	7.45	4.77	8.2	8.42	NLR-145	4.4	K.W. canal water
N. Arjunarao	1.20	23.36	14.51	8.0	8.43	BPT-5204	**	Drain water EC-(4.25); pH-(8.35)
N. Gandhi	0.40	15.16	5.65	8.0	8.76	BPT-5204	3.8	Drain water EC-(4.25); pH-(8.35)
S.S.R.K. Prasad	2.0	17.79	13.29	7.6	7.83	MTU-2716	4.7	Bore well EC-(3.50); pH-(8.20)

** *Poor establishment*

Evaluation of Zero Tillage System under Semi-Reclaimed Sodic Soil – Kanpur

The experiment was conducted at NARP Research Farm, Kanpur to evaluate zero tillage under semi-reclaimed sodic soils. The initial pH, EC_e and ESP value of soil were 10, 4.6 dS/m and 72 respectively.

Residual effect of different doses of gypsum showed significant improvement in grain and straw yield of rice and wheat (Table 108). Highest grain and straw yield of rice and wheat was recorded with the application of gypsum 100% GR (rice 4.13 and wheat 3.24 t/ha) and lowest in control (rice-1.42 and wheat 1.26 t/ha) respectively.

Table 108. Effect of gypsum with and without rice-straw incorporation on crop yields (t/ha)

Treatments	Conventional tillage				Zero tillage			
	Rice		Wheat		Rice		Wheat	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1	1.42	1.70	1.33	1.57	1.51	1.78	1.26	1.49
T_2	1.54	1.80	1.39	1.64	1.63	1.93	1.38	1.63
T_3	2.30	2.67	1.88	2.22	2.34	2.75	1.80	2.12
T_4	2.49	2.93	1.99	2.35	2.59	3.05	1.92	2.26
T_5	3.24	3.79	2.61	3.08	3.30	3.88	2.49	2.92
T_6	3.51	4.12	2.86	3.37	3.55	4.17	2.71	3.20
T_7	3.81	4.44	3.03	3.56	3.85	4.52	2.86	3.38
T_8	4.00	4.70	3.24	3.82	4.13	4.84	3.03	3.58

CD (5%)	Gypsum	Tillage	Straw Incorporation	Interaction
Rice-Grain	0.10	NS	0.07	NS
Rice-Straw	0.12	NS	0.09	NS
Wheat-Grain	0.12	NS	0.08	NS
Wheat-Straw	0.13	NS	0.09	NS

T_1: Control (Without Gypsum); T_2: T_1 + rice straw; T_3: Gypsum @ 25% GR; T_4: T_3+rice straw; T_5: Gypsum @ 50% GR; T_6: T_5+rice straw; T_7: Gypsum @ 100% GR; T_8: T_7+ rice straw

Incorporation of rice straw both under conventional and zero tillage numerically increased the grain and straw yield of rice and wheat but were non-significant. Conventional and zero-tillage practices showed marginal yield differences at all levels of gypsum application. In general, conventional tillage plots showed higher grain and straw yield of wheat than zero tillage plots, however, the reverse trend was observed in zero tillage plots with rice yield, although yield differences were non-significant.

Data on changes in soil characteristics presented in Table 109 revealed the beneficial effect of gypsum application. Initial pH_s value (10.0) dropped to 9.02, 8.79, 8.28 under conventional tillage and 9.00, 8.70, 8.38 under zero tillage in plots under treatment T_6, T_7 and T_8 respectively.

Table 109. Changes in chemical characteristics of soil (0-20 cm) after wheat (2008-09)

Treatments	Conventional tillage			Zero tillage		
	pH_s	EC_e (dS/m)	ESP	pH_s	EC_e (dS/m)	ESP
T_1	9.74	4.78	62.1	9.78	4.73	63.0
T_2	9.06	4.17	45.0	9.08	4.15	43.5
T_3	8.93	3.15	31.5	8.96	3.18	36.0
T_4	8.41	2.83	28.0	8.45	3.00	26.6
T_5	9.53	2.25	53.0	9.65	4.48	54.8
T_6	9.02	3.45	37.0	9.00	3.42	40.0
T_7	8.79	3.04	27.8	8.70	2.99	31.5
T_8	8.28	2.73	20.4	8.38	2.84	20.8

Notations are same as given in Table 108

Effect of Set Furrow method of Gypsum Application and Textural Modification on Soil Reclamation and Crop Performance - Indore

The experiment was conducted on black alkali soil at Barwaha having initial soil ESP of 55 to 60. Gypsum @ 100% of GR was applied in plough layer either alone or with sand (@ 25 and 50 t/ha) and equivalent quantity of gypsum and sand was applied in strips (60 cm wide) to a depth of 30 cm (Fig. 35). The crop was planted (date of sowing – 04.06.2008) with recommended package and practices. The date of first picking was 26.10.2008.

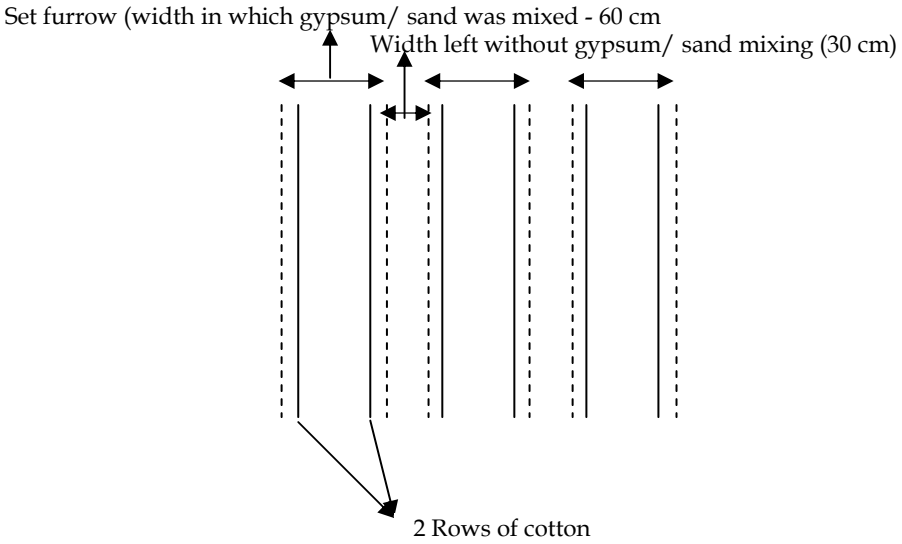


Fig. 35. Schematic view of set-furrow method of amendments application

The data in Table 110 revealed that the highest seed cotton yield (1.03 t/ha) was recorded when 50 tons of sand along with gypsum was incorporated into soil in a set furrow (T_6) system followed by T_5 (0.99 t/ha) where only gypsum was incorporated in set furrow. The treatment T_4 came at the third position in seed cotton yield where gypsum + sand @50 ton were applied in plough layer. The seed cotton yield decreased with increasing ESP of the soil.

Table 110. Seed cotton yield under set furrow method of gypsum application

Treatment	Seed cotton yield (t/ha)			
	RCH-2	RCH-118	RCH-138	Mean
T_1 - Control	0.37	0.34	0.30	0.34
T_2 - Surface mixing of gypsum @ 100% GR	0.82	0.71	0.69	0.74
T_3 - Surface mixing of sand @ 25 t/ha + gypsum @ 100% GR	0.91	0.79	0.75	0.82
T_4 - Surface mixing of sand @ 50 t/ha + gypsum @ 100% GR	0.98	0.89	0.86	0.91
T_5 - Mixing of gypsum in set furrow (60 x 30 cm)	1.04	0.98	0.94	0.99
T_6 - Mixing of sand + gypsum in set furrow (60 x 30 cm)	1.08	1.03	0.97	1.03
Mean	0.87	0.79	0.75	
	Main	Sub	Main x Sub	Sub x Main
CD (5%)	0.04	0.07	NS	NS

The data (Table 111) in respect of the soil properties in particular ESP revealed that the application of gypsum reduced soil ESP whereas application of sand at any rate was not able to show any considerable reduction in soil ESP.

Table 111. Soil properties recorded after eight years

Treatments	EC_e	pH_s	ESP
Initial	3.12	8.6	60.5
T_1 - Control	1.34	8.5	53.8
T_2 – Surface mixing of gypsum @ 100% GR	1.32	8.3	48.2
T_3 – Surface mixing of sand @ 25 t/ha + gypsum @ 100% GR	1.20	8.3	41.7
T_4 – Surface mixing of sand @ 50 t/ha + gypsum @ 100% GR	1.24	8.4	39.8
T_5 – Mixing of gypsum in set furrow of 60 x 30 cm	1.14	8.3	30.1
T_6 – Mixing of sand + gypsum in set furrow of 60 x 30 cm	1.10	8.2	28.6

Influence of Spent Wash and Spent Wash Vermi-Compost on Reclamation of Sodic Soils - Indore

The experiment was conducted during *kharif* and *rabi* seasons of 2008-09 at Salinity Research Station, Barwaha with paddy (var. Kranti)-wheat (GW-173) cropping sequence. The soil of the experimental field was sodic Vertisols (Table 112). Spent wash and spent wash vermi-compost was procured from the near by distillery. Characteristics of spent wash used as soil amendment and physico-chemical properties of spent wash vermi-compost and FYM are given in Table 113 and 114, respectively. The experiment was conducted in randomized block design with 9 treatments in 3 replications in plots measuring 5 x 4 m^2. The details of the treatments are as below:

One time application of spent wash and other treatments were given 30 days prior to transplanting of paddy seedlings. The crop was fertilized with 120 kg N, 60 kg P_2O_5, 40 kg K_2O and 25 kg $ZnSO_4$ /ha. Full doze of P_2O_5, K_2O and $ZnSO_4$ were applied as basal. The nitrogen was given in 3 equal splits i.e. at basal, at 25 days and 45 days after transplanting. The soil was puddled and 25 days old seedlings of paddy were transplanted with 20 cm x 10 cm spacing. The plots were submerged with 5 cm water throughout growing period.

Wheat crop was grown in same plots after harvesting of paddy for evaluating the residual effect of amendments. The wheat crop was fertilized with 120 kg N, 60 kg P_2O_5 & 40 kg K_2O/ha. Full doze of P_2O_5 and K_2O were applied as basal. Half of the nitrogen was given at the time of sowing as basal and remaining half of the nitrogen was given in two equal splits at 21 days and 42 days after sowing. The wheat crop was sown at 23 cm apart in rows. Total five irrigations were given to wheat crop. Plant samples were collected from each plot after paddy and wheat crop. The agronomical parameters were measured. Soil samples were collected at the end of wheat crop. The grain and straw samples were digested in di-acid mixture and were analyzed for Ca, Mg, Na and K by standard procedures. The soil samples were analyzed for organic carbon, available N, P, K pH_s, EC_e and ESP after the harvest of wheat crop.

Table 112. Physico-chemical properties of experimental soil

pHs	ECe (dS/m)	Ext. Na (meq/100g)	W.S. Na (meq/100g)	Exch. Na (meq/100g)	G.R. (t/ha)	CEC (cmol (p+)/kg	ESP
8.4	1.4	16.7	1.20	5.23	9.00	40.00	38.80

Ext.:Extractable; W.S. : Water soluble; Exch: Exchangeable; GR: Gypsum requirement; CEC: Cation exchange capacity; ESP : Exchangeable sodium percentage

Table 113. Characteristics of spent wash used as soil amendment

pH	EC (dS/m)	Ca	Mg	Na	K	N	S	BOD	COD
		mg/l							
4.98	9.42	1522	880	380	8675	990	1150	4110	20660

BOD: Biological oxygen demand; COD : Chemical oxygen demand

Table 114. Physico-chemical properties of spent wash vermi-compost and FYM

Organic	pH (1:4)	EC (dS/m)	Ca	Mg	K	S
			(%)			
Spent wash vermi-compost	8.5	3.8	0.78	0.38	1.10	0.55
Farm yard manure (FYM)	8.1	1.8	0.45	0.15	0.63	0.20

Yield attributing characters and yield of paddy

It is evident from Table 115 that the application of amendments in the soil significantly enhanced the growth and yield of paddy over control. The plant height of paddy varied significantly with different amendments. Application of 5.0 cm spent wash increased the plant height by 15.2% over control. Further increase in the levels of spent wash also increased the plant height but it was at par with 5.0 cm spent wash application. The number of tillers and length of panicle increased significantly over control with application of 5.0 cm spent wash. Further increase in the levels of spent wash application did not bring significant increase in number of tillers and length of panicle of paddy over 5.0 cm spent wash application. The highest grain (5.02 t/ha) and straw (5.92 t/ha) yield was recorded in 10.0 cm spent wash level but it was statistically at par with 5.0 cm. The application of 5.0 cm spent wash enhanced the grain and straw yield of paddy by 39.7 and 44.3 per cent, respectively over control

Table 115. Growth characters and yield of paddy as affected by amendments

Treatments	Plant height (cm)	Effective tillers/hill	Length of panicle (cm)	Yield (t/ha)	
				Grain	Straw
Control	80.0	6.5	17.5	3.47	3.95
FYM @ 5 t/ha	83.3	6.9	18.5	3.58	4.12
Vermi-compost @ 5 t/ha	84.1	7.0	19.3	3.67	4.23
Gypsum @75% GR	86.7	8.9	20.1	4.05	4.70
Gypsum@ 75% GR+FYM @ 5 t/ha	87.2	9.1	20.0	4.27	4.97
Gypsum @75% GR+VC @ 5 t/ha	87.9	9.4	20.3	4.35	5.05
SW 2.5 cm	88.3	9.9	20.7	4.38	5.13
SW 5.0 cm	92.2	10.5	22.5	4.85	5.70
SW 10.0 cm	93.1	10.6	22.7	5.02	5.92
CD (5%)	3.6	1.1	1.6	0.43	0.53

Nutrients uptake

The perusal of the data given in Table 116 revealed that the uptake of Ca, Mg and K by grain and straw of paddy increased significantly by the application of different amendments in comparison to control. The highest uptake of Ca, Mg and K by grain and straw was noticed at 10.0 cm spent wash level but it did not differ significantly with 5.0 cm spent wash level .The uptake of Na by grain and straw was found to decrease with application of different amendments as compared to control. The lowest uptake of Na by grain (18.2 kg/ha) and straw (22.5 kg/ha) was recorded with 10.0 cm spent wash. Uptake of Na by grain and straw with 5.0 cm spent wash application decreased by 15.1 and 12.6 per cent respectively over control.

Table 116. Nutrient uptake by paddy (kg/ha) as affected by amendments

Treatments	Grain				Straw			
	Ca	Mg	Na	K	Ca	Mg	Na	K
Control	10.6	5.1	22.5	14.6	7.6	5.3	27.0	33.7
FYM @ 5 t/ha	12.3	6.5	21.7	16.0	8.2	6.8	26.7	36.8
Vermi compost @ 5 t/ha	13.8	7.3	21.5	17.3	9.9	8.2	26.3	38.9
Gypsum @75% GR	16.6	10.2	20.9	21.6	13.2	10.3	26.0	49.3
Gypsum@ 75% GR+FYM @5 t/ha	19.7	11.1	20.5	24.2	14.9	11.6	25.8	54.5
Gypsum @75% GR+VC @ 5 t/ha	21.2	11.6	20.0	25.8	15.8	12.8	25.6	56.9
SW 2.5 cm	23.4	13.2	19.6	28.0	18.2	14.7	24.0	60.9
SW 5.0 cm	30.7	17.5	19.1	33.6	22.8	18.2	23.6	71.4
SW 10.0 cm	32.8	19.4	18.2	36.1	25.3	20.9	22.5	76.9
CD (5%)	4.45	2.20	NS	2.73	2.93	2.17	NS	6.57

Yield attributing characters and yield of wheat

The data on the effect of different amendments on plant height, number of effective tillers per plant and length of ear head of wheat are given in Table 117. It is evident that the plant height of wheat varied significantly with the application of different amendments. Application of 5.0 cm spent wash increased the plant height by 38.0% over control. Further increase in spent wash application also increased the plant height but the increase over 5.0 cm spent wash was statistically non-significant. The number of effective tillers per plant increased significantly with the applications of 5.0 cm spent wash over control. Further increase in the application of spent wash did not bring significant increase in number of effective tillers over 5.0 cm spent wash. Application of 5.0 cm spent wash significantly enhanced length of ear head of wheat by 42.0% over control. The highest grain (4.17 t/ha) and straw (4.47 t/ha) yield was obtained in 10.0 cm spent wash which was at par with 5.0 cm spent wash level. Application of 5.0 cm spent wash increased the grain and straw yield by 85.2 and 89.9 per cent, respectively over control.

Table 117. Growth characters and yield of wheat as affected by amendments

Treatments	Plant height (cm)	Effective tillers per plant	Length of ear head (cm)	Yield (t/ha)	
				Grain	Straw
Control	47.3	5.27	5.07	2.17	2.29
FYM @ 5 t/ha	48.7	5.40	5.20	2.27	2.44
Vermi compost @ 5 t/ha	50.0	5.60	5.40	2.33	2.54
Gypsum @75% GR	56.2	6.40	5.53	3.00	3.35
Gypsum@ 75% GR+FYM @5 t/ha	57.6	6.73	5.80	3.40	3.49
Gypsum @75% GR+VC @ 5 t/ha	59.3	6.80	6.00	3.47	3.55
SW 2.5 cm	62.0	6.87	6.60	3.52	3.85
SW 5.0 cm	65.3	7.67	7.20	4.02	4.35
SW 10.0 cm	66.0	7.93	7.33	4.17	4.47
CD (5%)	3.23	0.71	0.49	0.48	0.40

Nutrients uptake

The perusal of the data indicated that the highest uptake of Ca, Mg and K by grain and straw of wheat was at 10.0 cm spent wash application but it was at par with 5.0 cm spent wash. A reduction in uptake of Na by grain and straw portion of wheat was observed with addition of different amendments. The lowest uptake of Na by grain (12.5 kg/ha) and straw (21.9 kg/ha) was registered

with 10.0 cm spent wash. The per cent reduction in uptake of Na by grain and straw with 5.0 cm spent wash application was 16.7 and 13.6 respectively over control (Table 118).

Post harvest status of soil

Results showed that addition of different amendments to the soil significantly increased organic carbon, available N and K contents over control, while decreased the soil EC_e and ESP after harvest of wheat crop (Table 119). The highest organic carbon content (0.77%) was in plots where 10.0 cm spent wash was applied but it did not differ significantly with 5.0 cm spent wash (0.73%). The highest available N (207.3 kg/ha) and K (447 kg/ha) contents in the soil were recorded in the treatment receiving 10 cm spent wash but these were at par with 5 cm spent wash. Application of amendments did not affect the available P status of soil after harvest of wheat. A reduction in pH_s was also observed due to addition of amendments to soil but it was non- significant. The lowest EC_e (1.18 dS/m) and ESP (17.0) were noticed when 10 cm spent wash was applied, but it did not differ significantly with 5 cm level.

Table 118. Nutrient uptake by wheat (kg/ha) as affected by amendments

Treatments	Grain				Straw			
	Ca	Mg	Na	K	Ca	Mg	Na	K
Control	6.5	3.5	16.1	9.1	5.9	2.8	26.5	16.6
FYM @ 5 t/ha	7.4	4.3	15.2	10.2	6.8	3.4	25.6	18.4
Vermi Compost @ 5 t/ha	8.2	5.1	14.7	11.7	8.2	4.4	25.2	20.1
Gypsum @ 75% GR	14.4	9.0	14.3	17.4	12.5	8.1	25.0	28.8
Gypsum@ 75% GR+FYM @ 5 t/ha	17.5	10.7	14.1	21.8	13.9	9.1	24.5	31.4
Gypsum @ 75% GR+VC @ 5 t/ha	19.4	11.6	14.0	23.3	14.9	10.4	24.2	33.9
SW 2.5 cm	20.3	13.2	13.7	25.4	18.2	11.3	23.6	37.7
SW 5.0 cm	26.5	16.9	13.4	33.5	22.6	14.8	22.9	45.2
SW 10.0 cm	29.1	18.9	12.5	36.4	24.7	16.7	21.9	48.6
CD (5%)	2.52	2.47	NS	3.10	2.12	1.79	NS	4.55

Table 119. Effect of amendments on soil properties after the harvest of wheat

Treatments	OC (%)	Available nutrients (kg/ha)			pH_s	EC_e (dS/m)	ESP
		N	P	K			
Control	0.37	178.0	8.1	328	8.13	1.29	35.4
FYM @ 5 t/ha	0.46	186.7	9.0	335	8.10	1.28	34.6
Vermi compost @ 5 t/ha	0.47	188.3	9.2	339	8.10	1.26	34.2
Gypsum @ 75% GR	0.46	185.7	9.3	353	8.10	1.24	24.5
Gypsum @ 75% GR+ FYM @ 5 t/ha	0.52	189.7	9.9	361	8.10	1.22	23.5
Gypsum @ 75% GR+Vermi-compost @ 5 t/ha	0.54	192.3	9.9	373	8.10	1.22	21.9
SW 2.5 cm	0.62	194.0	10.0	383	8.10	1.20	19.7
SW 5.0 cm	0.73	202.7	11.7	421	8.10	1.20	17.1
SW 10.0 cm	0.77	207.3	11.7	447	8.10	1.18	17.0
CD (5%)	0.05	6.2	NS	35	NS	0.05	1.6

Response of Crops to Chemical and Organic Amendments in Alkali Vertisols - Gangawati

The area under alkali soils is vast in Northern Karnataka and there is need to manage these soils for better crop growth and yield. Application of chemical and organic amendments is an important option for increasing productivity of crops under alkali conditions. The present experiment was

conducted on farmer's field with sunflower and cotton as test crops. The field experiment was initiated during 2006 and continued during subsequent years to find the effect of chemical/organic amendments on crop growth and yield and on soil properties in an alkali soil.

Sunflower

The results obtained during 2008-09 and 2009-10 indicated that application of FYM @ 10t/ha + 50% of gypsum requirement (GR) recorded significantly higher seed yield of 18.13 q/ha when compared to control (12.42 q/ha) and application of gypsum at 50 per cent and 75 per cent of GR alone (15.19 and 14.82 q/ha respectively). The higher seed yield recorded with application of FYM @ 10 t/ha + 50% of GR remained at par with the application of FYM @ 10t/ha with 75% of GR (16.43 q/ha), application of vermicompost @ 2.5 t/ha with application of 50% of GR (16.86 q/ha) and 75% of GR (17.09 q/ha). The soil chemical properties revealed that the ESP was significantly lower in the case of FYM @ 10t/ha with 75% of GR (15.86) indicating improvement in soil physical condition (Table 120).

Cotton

The results revealed that application of FYM @ 10 t/ha + 75% of gypsum requirement (GR) recorded significantly higher kapas yield of 15.34 q/ha when compared to control (10.20 t/ha) and application of gypsum at 50% and 75% of GR alone (12.23 and 12.47 q/ha, respectively). The higher kapas yield recorded with application of FYM @ 10 t/ha with 75% of GR remained on par with the application of FYM @ 10t/ha with 50% of GR (14.68 q/ha), application of vermicompost @ 2.5 t/ha with 50% and 75% of GR (14.57 and 15.07 q/ha respectively). The soil ESP was lowest in the case of FYM @ 10t/ha with 75% of GR (Table 120).

Table 120. Effect of organic and inorganic amendments on yield of sunflower, cotton and soil ESP in alkal Vertisols

Treatment	Sunflower					Cotton				
	Seed yield (q/ha)			ESP		Kapas yield (q/ha)			ESP	
	2008-09	2009-10	Mean	2008-09	2009-10	2008-09	2009-10	Mean	2008-09	2009-10
T_1	17.83	18.42	18.13	21.2	17.7	14.02	15.33	14.67	20.7	17.6
T_2	16.30	16.56	16.43	17.3	15.9	14.45	16.23	15.34	16.6	15.7
T_3	16.83	16.88	16.86	21.5	17.9	13.94	15.20	14.57	19.9	17.3
T_4	17.10	17.07	17.09	21.1	16.6	14.22	15.92	15.07	17.1	16.1
T_5	14.93	15.44	15.19	24.0	21.3	11.36	13.09	12.25	20.7	19.3
T_6	14.90	14.74	14.82	20.4	18.6	11.77	13.17	12.47	16.7	16.4
T_7	12.53	12.31	12.42	27.2	26.8	9.84	10.56	10.20	24.8	24.0
S Em ±	0.6	0.68		1.72	0.56	0.38	0.48	0.43	0.93	0.12
CD (5%)	1.85	2.08				1.18	1.47		NS	0.23

T_1: FYM @ 10 t/ha + 50% of gypsum requirement; T_2: FYM @ 10t/ha + 75% of gypsum requirement
T_3: Vermi-compost @ 2.5 t/ha + 50% of gypsum requirement; T_4: Vermi-compost @ 2.5 t/ha + 75% of gypsum requirement; T_5: 50% of gypsum requirement; T_6: 75% of gypsum requirement; T_7: Control (No amendments)

Land and Rain Water Management Strategies for Cultivation in Rainfed Sodic Soils - Gangawati

The experiment comprising different rainwater harvesting practices along with gypsum application viz., deep ploughing with 75% and 50% gypsum requirement, Tied ridges with 75% and 50% gypsum requirement, compartment bunding with 75% and 50% gypsum requirement and flat bed with 75% and 50% gypsum requirement was conducted to study the effect on crop (sunflower) performance and soil chemical parameters since 2005-06 and continued in 2008-09 and 2009-10 in the rainfed sodic soils on farmers field. Treatments were imposed during the beginning of the monsoon, so that sufficient rainwater was harvested and salts are leached before the sowing was taken up.

Yield attributing parameters of sunflower (var. Gangakavery) showed that the crop performed better under tied ridges with 75% gypsum application. Highest seed yield was obtained in tied ridges with 75% gypsum requirement treatment during both the years (2008-09 and 2009-10). Highest mean seed yield (0.95 t/ha) was obtained in tied ridges with 75% gypsum followed by tied ridges with 50% gypsum (0.92 t/ha), deep ploughing with 75% gypsum (0.8 t/ha), compartment bunding with 50% gypsum (0.79 t/ha), deep ploughing with 50% gypsum (0.78 t/ha), compartment bunding with 50% gypsum (0.77 t/ha), flat bed with 75% gypsum (0.68 t/ha), flat bed with 50% gypsum (0.62 t/ha) and least (0.52 t/ha) in case of flat bed without gypsum application (Table 121).

Table 121. Effect of different moisture harvesting practices and amendment on seed yield of sunflower and soil ESP

Treatments	ESP		Seed yield (t/ha)		
	2008-09	2009-10	2008-09	2009-10	Mean
Compartment bunding (75% GR)	17.5	16.2	0.74	0.85	0.79
Compartment bunding (50% GR)	19.6	17.8	0.71	0.83	0.77
Tied ridges (75% GR)	16.3	16.0	0.89	1.01	0.95
Tied ridges (50% GR)	19.3	18.8	0.86	0.97	0.92
Ploughing (75% GR)	16.1	17.2	0.76	0.84	0.8
Ploughing (50% GR)	18.5	19.4	0.75	0.81	0.78
Flat bed (no gypsum)	23.2	22.9	0.48	0.55	0.52
Flat bed (75% GR)	20.6	21.4	0.62	0.73	0.68
Flat bed (50% GR)	22.1	21.2	0.58	0.66	0.62
CD (5%)			0.76	0.08	

Data on the effect of different moisture harvesting practices on soil ESP indicated leaching of salts under all the practices compared to initial. Leaching of salts was maximum under tied ridges. The effect of rainwater harvesting on leaching of salts was minimum under flat bed (control).

Effect of Long-Term Application of Organic/Green Manures in Sodic Vertisols - Indore

The various green manuring crops were cultivated in differentially gypsum applied plots (to create different levels of soil ESP) as per the treatments. The application of gypsum was done once only before sowing of green manuring crop in the month of April/ May 2005. The green manure crop was cultivated and buried in soil at the age of 45 days well before the sowing of the *kharif* crop. The paddy – wheat crop rotation would be followed.

Effect of green manures/ FYM on grain and straw yield of paddy

Paddy yield as influenced by application of green manures and FYM at different soil ESP is presented in Table 122. The grain yield of paddy decreased significantly with increase in soil ESP. Incorporation of green manure increased the paddy yield significantly over control. Highest mean grain yield of paddy was recorded during the years 2008-09 and 2009-10 in case of dhaincha (2.0 and 2.11 t/ha) followed by sunhemp (1.8 and 5.2 t/ha) at soil ESP of 25 respectively. Lowest yield was observed in control plot.

Effect on wheat grain yield

The data in Table 123 revealed that grain yield of wheat decreased with increase in soil ESP. Incorporation of green manure enhanced the grain yield of wheat significantly over control. Interaction effects were also significant. Highest mean grain yield of wheat (2008-09 and 2009-10) was recorded in case of dhaincha (2.7 and 2.9 t/ha). The lowest was observed in control plot.

Table 122. Grain yield (t/ha) of paddy as influenced by application of green manures/ FYM

Green manures	Soil ESP				
	25	35	45	50	Mean
			2008-09		
Control	2.0	1.9	1.3	1.0	1.5
FYM @ 10 t/ha	2.0	2.0	1.4	1.1	1.6
Dhaincha	2.3	2.1	2.0	1.5	2.0
Sunhemp	2.2	2.0	1.8	1.4	1.8
Mean	2.1	2.0	1.6	1.3	
CD (5%)	ESP: 0.12; FYM/GM: 0.14; ESPxFYM/GM: NS; FYM/GMxESP: NS				
			2009-10		
Control	1.8	1.5	1.3	1.0	1.4
FYM @ 10 t/ha	1.9	1.8	1.6	1.3	1.6
Dhaincha	2.4	2.3	2.1	1.7	2.1
Sunhemp	2.2	2.1	1.9	1.6	1.9
Mean	2.1	1.9	1.7	1.4	
CD (5%)	ESP: 0.15; FYM/GM: 0.06; ESPxFYM/GM: NS; FYM/GMxESP: NS				

Table 123. Grain yield (t/ha) of wheat as influenced by application of green manures/ FYM

Green manures	Soil ESP				
	25	35	45	50	Mean
			2008-09		
Control	2.1	1.9	1.6	1.3	1.7
FYM @ 10 t/ha	2.7	2.5	2.0	1.6	2.2
Dhaincha	3.4	2.9	2.3	2.0	2.7
Sunhemp	3.0	2.8	2.2	1.9	2.5
Mean	2.8	2.5	2.0	1.7	
CD (5%)	ESP: 0.18; FYM/GM: 0.09; ESPxFYM/GM: 0.23; FYM/GMxESP: 0.18				
			2009-10		
Control	2.6	1.9	1.9	1.7	2.0
FYM @ 10 t/ha	2.9	2.3	2.3	2.0	2.4
Dhaincha	4.1	2.7	2.4	2.4	2.9
Sunhemp	3.8	2.5	2.3	2.2	2.7
Mean	3.4	2.3	2.2	2.1	
CD (5%)	ESP: 0.25; FYM/GM: 0.17; ESPxFYM/GM: 0.39; FYM/GMxESP: 0.35				

Effect of green manures/ FYM on soil properties

The data revealed that pH and EC_e of soil remained nearly the same. However, the ESP values slightly decreased with the incorporation of green manures/FYM at all the levels. The lowest ESP was recorded in case of dhaincha followed by sunhemp (Table 124).

Table124. Soil ESP as influenced by application of green manures/ FYM

Green manures	Soil ESP				
	25	35	45	50	Mean
			2008-09		
Control	24.5	33.8	43.2	48.4	37.5
FYM @ 10 t/ha	22.2	32.1	42.2	46.5	35.8
Dhaincha	20.2	30.1	38.4	43.2	33.0
Sunhemp	20.8	30.6	39.8	44.2	33.9
Mean	21.9	31.7	40.9	45.6	
			2009-10		
Control	24.3	33.6	42.7	47.7	37.1
FYM @ 10 t/ha	21.1	30.9	40.4	44.6	34.3
Dhaincha	18.8	28.9	36.4	41.0	31.3
Sunhemp	20.5	29.8	40.1	42.9	33.4
Mean	21.2	30.8	39.9	44.1	

Studies on Crop Performance after Tree Harvesting in Alkali Soil Environment – Indore

A field experiment based on the findings of preliminary screening was planned in split plot design with 9 tree species in main plots and 2 methods of planting in sub-plots. The methods of planting comprised of (i) conventional pits of 45 x 45 x 45 cm (T_1) and (ii) pit auger hole of 45 x 45 x 45 cm pit followed by auger hole of 30 cm depth and 30 cm diameter (T_2).

The tree species were removed from the plots by JCB. The plot wise soils samples were collected for analysis to know the physico-chemical properties of the experimental soil before sowing of wheat crop. Physico-chemical properties of the soil after 14 years of plantation and after removal of tree species (before sowing of wheat) were given in biennial report for the 2006-08.

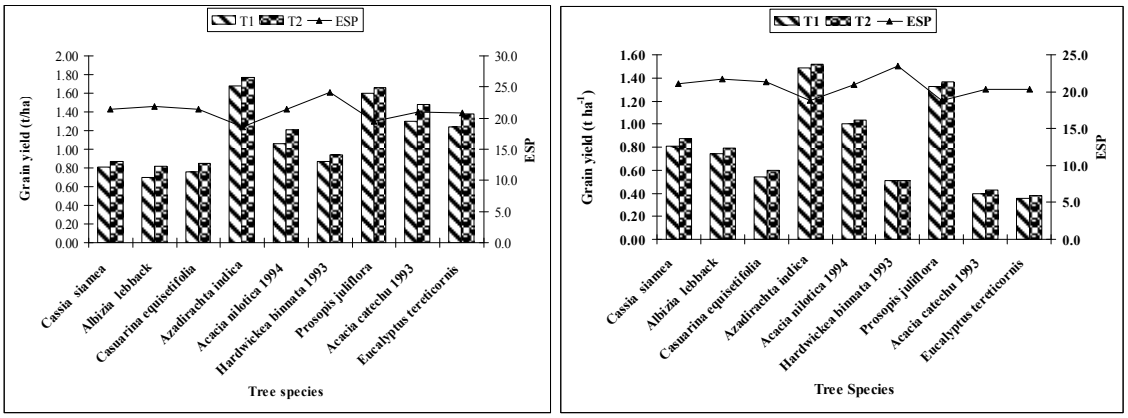
Sorghum

Maximum grain yield of sorghum (1.73 and 1.50 t/ha) was noticed in the plots where *Azadirachta indica* was planted followed by *Prosopis juliflora* (1.63 and 1.35 t/ha) in the year 2008-09 and 2009-10 respectively (Table 125) as low values of ESP were noticed under these treatments. Grain yield of sorghum increased with the decrease in ESP (Fig. 36).

Table 125. Effect of planting of tree species for 14 years on grain yield (t/ha) of sorghum

Tree species planted in 1990	Tree Species replaced by (due to poor survival)	2008-09			2009-10		
		T_1	T_2	Mean	T_1	T_2	Mean
Cassia siamea	-	0.81	0.87	0.84	0.81	0.88	0.84
Albizia lebback	-	0.71	0.82	0.76	0.74	0.79	0.77
Casuarina equisetifolia	-	0.76	0.85	0.81	0.54	0.60	0.57
Azadirachta indica	-	1.68	1.77	1.73	1.48	1.52	1.50
Acacia auriculiformisa	*Acacia nilotica* 1994	1.07	1.21	1.14	1.00	1.03	1.02
Dalbergia sisoo	*Hardwickea binnata* 1993	0.87	0.95	0.91	0.51	0.51	0.51
Prosopis juliflora	-	1.60	1.66	1.63	1.33	1.37	1.35
Dendrocalamus strictus	*Acacia catechu* 1993	1.30	1.48	1.39	0.40	0.43	0.42
Eucalyptus tereticornis		1.24	1.38	1.31	0.35	0.38	0.37
Mean		1.11	1.22		0.80	0.83	
		Main	Sub	M x S	Main	Sub	M x S
CD (5%)		0.07	0.20	0.28	0.05	NS	NS

T_1 : Conventional pits of 45x45x45 cm; T_2 : Pit auger hole method of plantation



2008-09 2009-10

Fig 36. Effect of tree species as well as methods of planting on sorghum yield and soil ESP

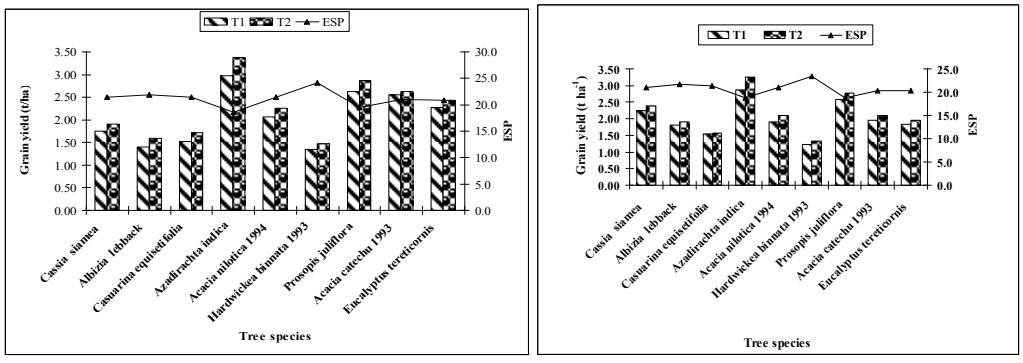
Wheat

The data (Table 126) revealed that the maximum grain yield of wheat (3.17 and 3.06 t/ha) was in plots where *Azadirachta indica* was planted followed by *Prosopis juliflora* (2.75 and 2.69 t/ha) in the year 2008-09 and 2009-10, respectively. An increasing trend was observed in wheat yield with the decrease in ESP (Fig. 37). The changes in ESP were non-significant.

Table 126. Effect of planting of trees for 14 years on grain and straw yield (t/ha) of wheat

Tree Species	Tree Species replaced by	2008-09			2009-10		
planted in 1990	(due to poor survival)	T_1	T_2	Mean	T_1	T_2	Mean
Cassia siamea	-	1.75	1.91	1.83	2.23	2.38	2.31
Albizia lebback	-	1.41	1.59	1.50	1.82	1.90	1.86
Casuarina equisetifolia	-	1.53	1.72	1.63	1.56	1.56	1.56
Azadirachta indica	-	2.97	3.38	3.17	2.87	3.25	3.06
Acacia auriculiformisa	*Acacia nilotica* 1994	2.06	2.25	2.16	1.91	2.09	2.00
Dalbergia sisoo	*Hardwickea binnata* 1993	1.34	1.47	1.41	1.23	1.33	1.28
Prosopis juliflora	-	2.63	2.88	2.75	2.59	2.78	2.69
Dendrocalamus strictus	*Acacia catechu* 1993	2.56	2.63	2.59	1.95	2.11	2.03
Eucalyptus tereticornis		2.28	2.44	2.36	1.84	1.95	1.90
Mean		2.06	2.25		2.00	2.15	
		Main	Sub	M x S	Main	Sub	M x S
CD (5%)		0.06	0.15	NS	0.12	0.17	NS

T_1 : Conventional pits of 45x45x45 cm; T_2 : Pit auger hole method of plantation



2008-09 **2009-10**

Fig 37. Effect of tree species as well as methods of planting on wheat yield and soil ESP

Effect of Switching Over to Upland Cropping Sequence on Re-Sodification and Sustainability of Crop Yield in Reclaimed Sodic Soil under Constrained Water Supply Conditions - Kanpur

An experiment was conducted at NARP Research Farm, Dalipnagar, Kanpur to study the effect of gypsum with and without application of green manure dhaincha (*Sesbania aculeata*) on sustainability of reclamation with paddy-wheat, fallow-wheat, sorghum-mustard cropping sequences in sodic soils. The initial pH, EC_e and ESP of the soil were 10.15, 6.5 dS/m and 83 respectively.

The mean yield data showed beneficial effect of gypsum application and showed significant difference in treatments over control (Table 127). Studies on residual effect of gypsum (applied once in 1997) revealed significant increase in grain and straw/stock yield of rice, wheat, sorghum and mustard in cropping sequence of rice-wheat, fallow-wheat and sorghum-mustard. Application of gypsum @ 50 & 100% GR recorded 68 and 95 per cent increase in yield respectively. Application of gypsum @ 50 & 100% G.R. along with green manure recorded 70 and 80 per cent higher yield respectively over green manure alone. It may be interesting that plots are incorporated with GM in fallow-wheat cropping sequence, higher grain and straw yield of wheat were obtained in comparison to rice-wheat cropping sequence but yield differences were marginal.

Table 127. Effect of gypsum and green manuring on crop yields (t/ha) in reclaimed sodic soil under water supply constraints (2008-09)

Treatments	Rice-Wheat				Fallow-Wheat			Sorghum-Mustard			
	Rice		Wheat		Fallow	Wheat		Sorghum		Mustard	
	Grain	Straw	Grain	Straw		Grain	Straw	Grain	Straw	Grain	Straw
T_1	2.61	3.13	1.74	2.09	-	1.78	2.10	0.99	8.19	0.85	3.83
T_2	4.10	4.92	3.36	3.96	-	3.35	3.96	2.03	12.49	1.44	5.67
T_3	4.97	5.96	3.82	4.51	-	3.87	4.57	2.30	13.46	1.73	5.89
T_4	2.85	3.44	2.01	2.51	-	2.09	2.50	1.09	10.09	0.95	4.27
T_5	4.48	5.77	3.66	4.32	-	3.71	4.40	2.12	13.91	1.58	6.12
T_6	4.90	5.89	4.01	4.73	-	4.11	4.85	2.38	13.80	1.89	6.54
CD (5%)											
Gypsum	0.13		0.12								
Green manuring	0.12		0.09								
Rotation	0.10		0.11								
Interaction	NS		NS								

T_1 : No amendments (control); T_2 : Gypsum @ 50% GR; T_3 : Gypsum @ 100% GR;
T_4 : No amendments + dhaincha (Sesbania aculeata); T_5 : Gypsum @ 50% GR + dhaincha;
T_6 : Gypsum @ 100% GR + dhaincha

The application of green manuring *in-situ*, once in every year (before *kharif* season) in combination with different doses of gypsum (residual), increased the grain and straw/stock yield of rice, wheat, sorghum and mustard. The results indicated that green manuring (once in a year) and one time application of gypsum is beneficial for the crop production and soil health.

Changes in surface (0-20 cm) soil characteristics revealed the beneficial effect of gypsum application. pH_s values dropped drastically from initial 10.15 to 8.10 and 7.93 in plots treated with gypsum @ 50% and 100% GR along with green manuring respectively (Table 128). EC_e and ESP values also dropped considerably from initial 6.5 to 1.95 and 0.90 dS/m and 49.0 to 12.0 and 9.0 when treated with gypsum 50% and 100% GR along with green manuring respectively.

Table 128. Effect of gypsum and green manuring on soil properties (0-20 cm) in reclaimed sodic soil under water supply constraints

Treatments	Rice-Wheat			Fallow-Wheat			Sorghum-Mustard		
	pH_s	EC_e (dS/m)	ESP	pH_s	EC_e (dS/m)	ESP	pH_s	EC_e (dS/m)	ESP
T_1	9.11	4.49	40.0	9.10	4.53	49.0	9.13	8.54	46.8
T_2	8.30	2.27	14.8	8.53	2.38	17.0	8.48	2.43	18.8
T_3	8.07	0.94	12.1	8.22	1.00	13.0	8.26	0.99	14.3
T_4	8.73	4.31	35.1	8.74	4.41	41.0	8.76	4.42	41.5
T_5	8.10	1.95	12.4	8.26	2.11	15.3	8.23	2.10	14.8
T_6	7.93	0.90	9.0	8.04	1.00	10.9	8.03	0.98	10.8

T_1 : No amendments (control); T_2 : Gypsum @ 50% GR; T_3 : Gypsum @ 100% GR; T_4 : No amendments + dhaincha (Sesbania aculeata); T_5 : Gypsum @ 50% GR + dhaincha; T_6 : Gypsum @ 100% GR + dhaincha

Monitoring and Evaluation of Large Scale Drainage Projects in the State of Haryana -Karnal

During 2008-09 and 2009-10 Beri and Dadri projects were completed as envisaged in the project document. Dhanana, Jagsi and Rori (Darbakalan) are in progress. The final monitoring results in the Dadri project showed a vast improvement in soil quality and rice yield (Table 129). The drainage designs for Jhajjar (Phase II) and Ban Mandori were prepared (Fig. 38 and Fig. 39). In the second phase, proposals for additional projects under RKVY would be prepared and sent to the government for funding under HOPP.

Table 129. Soil salinity, alkalinity and rice grain yield in the Dadri project (*Kharif* 2008)

Variables/Village	No. of observations	Range	Mean
	Village Khatiwas		
EC_2 (dS/m)	17	0.25 – 2.00	0.94
pH_2	17	7.80 – 8.55	8.04
Rice grain yield (t/ha)	17	1.50 – 5.00	3.15
	Village Loharwara		
EC_2 (dS/m)	29	0.35 – 1.45	0.87
pH_2	29	7.8 – 8.3	8.07
Rice grain yield (t/ha)	28	1.50 – 3.50	2.40
	Overall mean		
EC_2 (dS/m)	46	0.17 – 2.05	0.90
pH_2	46	7.8 – 8.3	8.06
Rice grain yield (t/ha)	45	1.29 – 4.15	2.68

The initial survey (Table 130) in Dhanana revealed that nearly 25% of the land is affected by water logging and soil salinity and consequently low yields (Table 131). Although pumping from the sump is limited, a redeeming feature has been that the farmers of Jagsi and Dhanana are pumping water from the manholes falling in their fields. They use the pumped water to irrigate their fields such that a manhole becomes a source of water. Besides, such a development helps in pumping of the ground water and might sensitize the farming community to go for individual subsurface drainage systems.

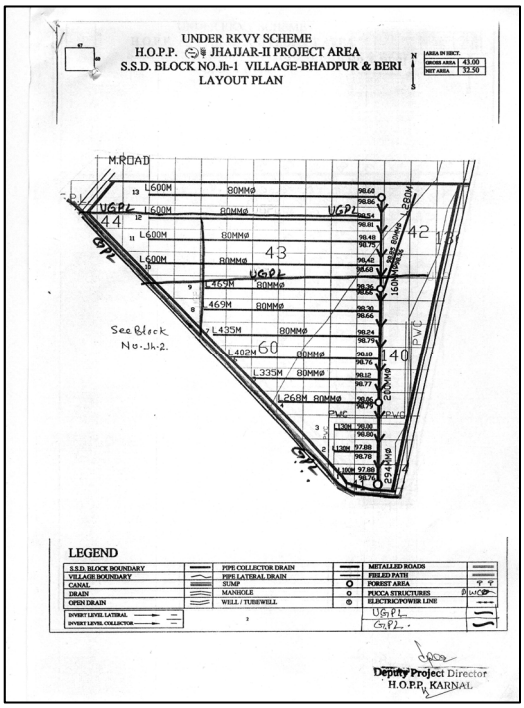


Fig. 38. Drainage plan of Bhadpur and Beri

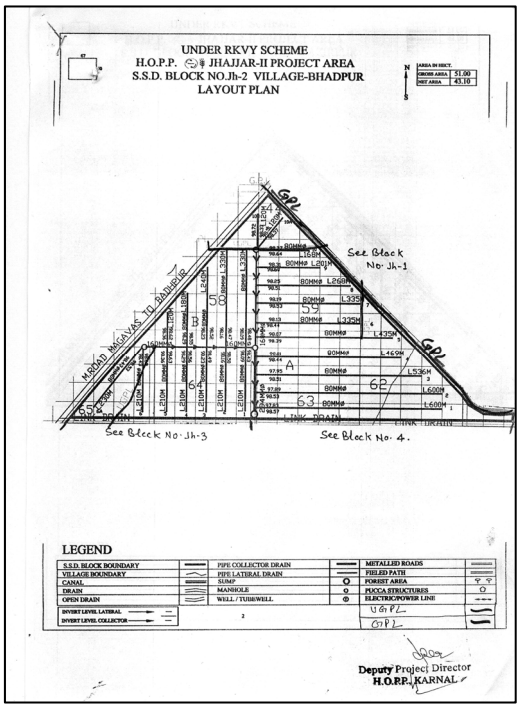


Fig. 39. Drainage plan of Bhadpur

Table 130. Salt affected areas in Dhanana project

Particulars	Area (ha)	Percentage to total operational holding
Normal soil	1.70	48.02
Alkali soil	0.05	1.41
Saline soil	0.88	24.86
Waterlogged soil	0.87	24.58
Total owned land	3.50	98.87
Leased-in land	0.04	1.13
Leased-out land	0.00	0.00
Net operational holding	3.54	100.00

Table 131. Soil salinity, alkalinity and wheat grain yield in Dhanana project (*Rabi*, 2008-09)

Variables/ Village	No. of observations	Range	Mean
Village: Dhanana			
EC_2 (dS/m)	45	0.10 – 4.76	1.01
pH_2	45	7.10 – 9.26	7.94
Wheat grain yield (t/ha)	45	0.83 – 2.91	1.88

The other notable achievements in the project are as follows:

Pump-cum-gravity outlets

In order to minimize the cost of pumping, gravity-cum-pumped outlets have been provided at few places wherever these are technically feasible. A desk study revealed that under the prevailing water table conditions in the Beri area as much as 75% of the cost of pumping could be saved with this provision (Table 132). In fact, with such a system, there would be no need to pump water for water and salt balance as this requirement could be fully met with the gravity flow. Pumping for irrigation

purpose would only be needed for which farmers have no hesitation in investing on pump and operational cost.

Table 132. Variation of discharge through orifice at different heads and pumping

Months	Depth to water table (Av. 2004-07) (cm)	Depth of orifice (cm)	Height above orifice (cm)	Diameter of orifice (cm)	Discharge through orifice (lps)	Discharge through pumping (lps)	Volume drained by pump per day (m^3/day) (8 hr/day)	Volume drained by orifice (m^3/day) (24hr/day)
Jan	50.0	65.0	15.0	7.2	4.3	10.0	288.0	367.9
Feb	55.0	65.0	10.0	7.2	3.5	10.0	288.0	300.4
Mar	50.0	65.0	15.0	7.2	4.3	10.0	288.0	367.9
Apr	65.0	65.0	0.0	7.2	0.0	10.0	288.0	0.0
May	73.0	65.0	0.0	7.2	0.0	10.0	288.0	0.0
Jun	80.0	65.0	0.0	7.2	0.0	10.0	288.0	0.0
Jul	63.0	65.0	2.0	7.2	1.6	10.0	288.0	134.4
Aug	54.0	65.0	11.0	7.2	3.6	10.0	288.0	101.6*
Sep	41.0	65.0	24.0	7.2	5.4	10.0	288.0	155.1*
Oct	36.0	65.0	29.0	7.2	5.9	10.0	288.0	165.0*
Nov	37.0	65.0	28.0	7.2	5.8	10.0	288.0	502.7
Dec	38.0	65.0	27.0	7.2	5.7	10.0	288.0	493.6
Total	642.0	780.0	161.0	86.4	40.0	120.0	3456.0	2588.8
Average	53.5	65.0	13.4	7.2	3.3	10.0	288.0	215.7

**submerged orifice for 20 days*

Modelling water table and salinization desalinization

Wasim model was used to assess the post drainage situation of the water table under wet (25% above normal rainfall), normal and dry rainfall (25% below normal rainfalls) years. Two years data for each case were used assuming that 2 years of above normal rainfall would be followed by 2 years of normal (485 mm) and 2 years of below normal rainfall. The predictions shown in Fig. 40 reveal that at no time water table reaches 0-30 cm layer under drainage situation. Since the total rainfall and the rainfall storms determine the rise of the water table, the water table in normal and above normal rainfall for this particular case were not very different. However, the water table during dry years remained lower than normal or above normal rainfall years. It appears that under the drainage situation, chances of aeration problem are quite less.

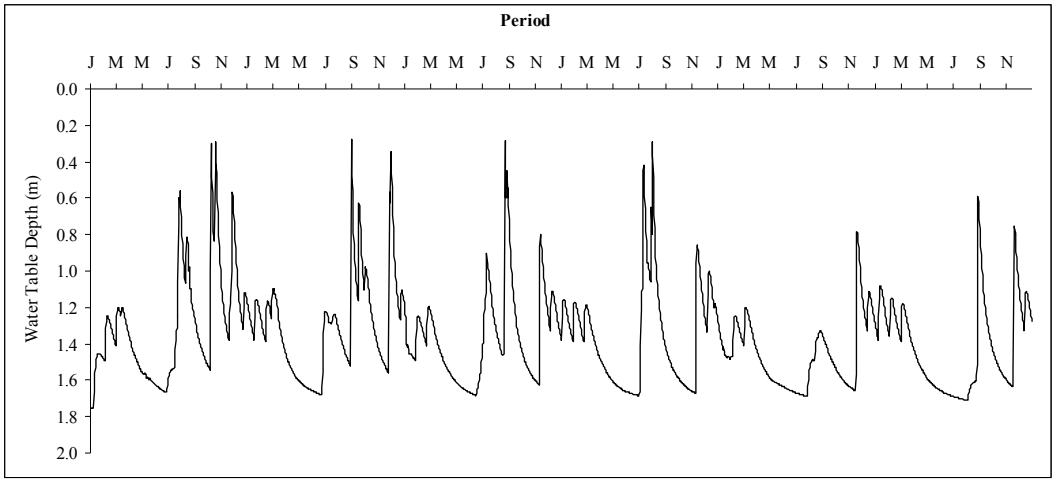


Fig. 40. Ground water table behavior in wet normal and dry years under drainage

Although the provision of drainage helps in reclaiming the land but reuse of drainage effluent for crop production during the *rabi* season may cause soil salinization. On the other hand desalinization would occur during the monsoon season. To see the variation in soil salinity under this situation, a case study was prepared for the wheat crop wherein saline water (5 dS/m) was used to apply 4 irrigations following pre-sowing irrigation with fresh water. Results revealed build-up of salts during the *rabi* reason due to irrigation with saline water. The soil salinity at the time of wheat harvest reached a level of 2.5 dS/m (EC_2), which is not detrimental to wheat crop at this stage. The soil salinity remained at that level and decreased with on-set of monsoon season (Fig. 41). Several combinations of such exercises revealed that:

- There is no build-up of soil salinity on a long-term basis
- Salinity build-up on year to year basis may occur depending upon the amount of rainfall. This may be taken care off by applying a heavy pre-sowing irrigation on short-term basis but over the long-term above normal rainfall would take care of the residual build-up in soil salinity.

From these studies it could be concluded that drainage helped in controlling the water table and facilitated the reuse of drainage water. Besides, it also helped in concluding that Wasim Model could be used in monitoring and evaluation of various management options that could be applied to manage drained lands to get maximum advantage of land drainage with minimum cost.

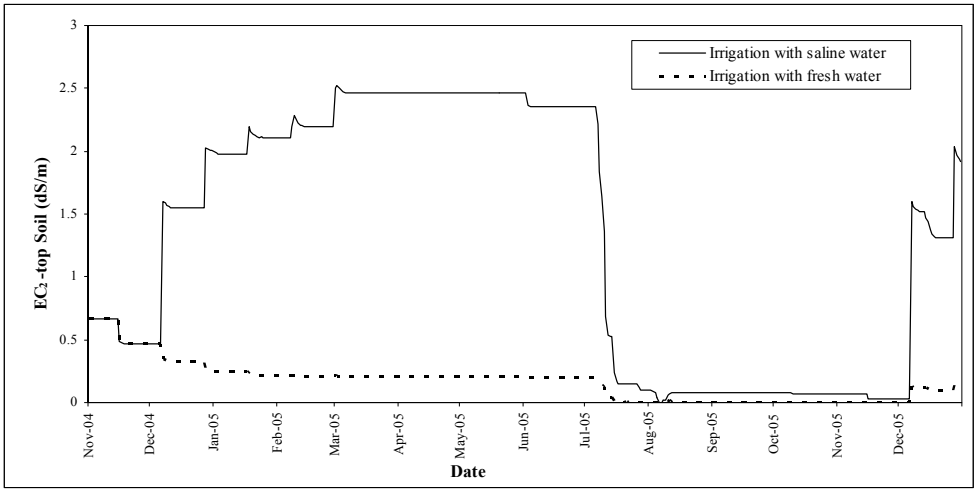


Fig. 41. Soil salinization and desalinization in saline water irrigated land in monsoon climate conditions with subsurface drainage

Subsurface Drainage for Heavy Soils of Maharashtra and Karnataka under Public Private Partnership Mode -Karnal

The MOU between CSSRI and Rex Polyextrusion Ltd., Sangli was extended for the year 2009-10 on the previous terms and conditions. The MOU provides for technical guidance to Rex group in drainage investigations, design and monitoring, capacity building and for organization of farmers training programmes. It also provides for technical inputs to location specific problems that might arise in laying out drainage projects. During the year 2009-10, farmers raised several issues on drainage materials and reclamation techniques with the Department of Water Resources. These issues were discussed at various levls including the farmers' representatives. Several location specific clogging of pipes with plant roots was reported. The problem was investigated by CSSRI and other drainage experts invited by the Rex group. It transpired that the roots of *Prosopis* enters the pipes and proliferate thereby blocking the flow partially or fully. On the basis of the discussions held following recommendations were made.

- On-farm land development: Land development including uprooting of *Prosopis*, field bunding, deep plowing and land leveling
- Leaching of salts: Intermittent leaching is recommended for the kind of soils existing in the project
- Green manuring: Incorporation of organic green manure from various sources
- Gypsum to improve soil structure: Gypsum may be applied wherever necessary in severely affected lands based on soil test results
- Salt tolerant varieties: Cultivation of salt tolerant crops in the initial 2 years such as sorghum and pearl millet in *kharif* and barley, mustard, wheat and sugar beet in the *rabi* season

With such a package and good management, the land reclamation can be accomplished within 2-3 years. Once the land is reclaimed, sugarcane could be grown

Individual farmer's response to land drainage

As per reports available from the Rex Group, a large number of farmers are opting for subsurface drainage as a land reclamation measure. More than 100 farmers have installed subsurface drainage on their fields with area ranging from 0.4 ha to about 25 ha. It has been made possible because of the gravity outlets available in the region. As such, farmers' don't wait for the response of other farmers and straightway go for the SSD installation on their fields (Table 133). Similar experiences in the Ukai Kakrapar Project in Gujarat have been reported by Navsari Agricultural University, erstwhile centre of Indo-Dutch Network Project. It appears that once the land reclamation is seen by the farmers, they are willing to have one time investment provided there is no or minimal post drainage management/expenses.

Table 133. Partial list of farmers opting for individual SSD on their fields

S.No.	Name of Farmers	Village	Scheme area (ha)
1.	Sh. Dipak Japtiwale	Kasabe Digraj, Taluka Miraj, Dist. Sangli	1.6
2.	Sh. Babasaheb Patil	Kasabe Digraj, Taluka Miraj, Dist. Sangli	2.0
3.	Sh. Abasaheb Patil	Khubi, Taluka Karad, Dist. Satara	1.7
4.	Sh. Abhijit B. Balighate	Shirdhone	1.6
5.	Sh. Raju Magadum	Nandani, Taluka Shirol, Dist. Kolhapur	0.8
6.	Sh. K.B.Patil, Nandani	Nandani, Taluka Shirol, Dist. Kolhapur	1.0
7.	Sh. Kakasaheb Patil	Shigur Taluka Athani, Dist. Belgaum	3.2
8.	Sh. Rahul Shah	Ugar Taluka Athani, Dist. Belgaum	4.0
9.	Sh. Nanasaheb Patil	Kasegaon Taluka Walawa, Dist. Sangli	0.4
10.	Sh. Balasaheb Shivarkar	Yavat Dist. Pune	1.8

Drainage Investigations, development of Design Criteria, Design and Installation of Subsurface Drainage Systems and Monitoring for controal of Water logging and Salinity in Heavy Textured Soils of Appikatla, Krishna Western Delta - Bapatla

Drainage system performance

Under CPVC drainage system, the mean salinity build-up in 30 m spaced drain area is 2.30, 2.75 and 2.77 dS/m during 2006-07, 2007-08, 2008-09 respectively and in case of 60 m spaced drain area 3.23, 4.51, 3.29 dS/m during 2006-07, 2007-08, 2008-09 respectively. Under Stoneware pipe drainage system, the mean salinity build-up in 30 m spaced drain area is 2.12, 1.58 and 2.17 dS/m during 2006-

07, 2007-08, 2008-09 respectively and in case of 60 m spaced drain area, are 2.98, 3.66, 3.48 dS/m during 2006-07, 2007-08, 2008-09 respectively. Both the data sets revealed slightly higher values of salinity in 60 m over 30 m drain spacing (Table 134).

Table 134. Drainage system performance under different drain materials (2006-09)

Performance indicator	CPVC drainage system with different spacing		Stoneware pipe drainage system with different spacing	
	30 m	60 m	30 m	60m
		2006-07		
Soil salinity (dS/m) (March/April 2007)	2.30	3.23	2.12	2.98
Paddy crop yield (t/ha) (Jan 2007)*	2.10*	2.28*	2.09*	1.86*
		2007-08		
Soil salinity (dS/m) (March/April 2008)	2.75	4.51	1.58	3.66
Paddy crop yield (t/ha) (Jan 2008)	6.63	6.57	6.86	6.51
		2008-09		
Soil salinity (dS/m) (March/April 2009)	2.77	3.29	3.17	3.48
Paddy crop yield (t/ha) (Jan /Feb 2009)	6.34	6.11	6.37	6.18

** Due to Ogni cyclone crops remained under submerged condition for a week and poor yields reported*

In order to segregate the effect of drainage material and drain spacing, the data of the last 3 years analyzed and presented in Table 134. The rice yield performance in 30 m spaced CPVC drain area was 2.10, 6.63, 6.34 t/ha during 2006-07, 2007-08, 2008-09 respectively and in case of 60 m spaced drain area, it was 2.28, 6.57 and 6.11 t/ha during 2006-07, 2007-08, 2008-09 respectively. The rice yield performance in 30 m spaced SW pipe drain area is 2.09, 6.86, 6.37 t/ha during 2006-07, 2007-08, 2008-09 respectively and in case of 60 m spaced drain area, are 1.86, 6.51 and 6.18 t/ha during 2006-07, 2007-08, 2008-09 respectively. Apparently, 30 m spaced drains are more effective during the initial years of subsurface drainage operation in terms of improving yield and controlling salinity compared to 60 m spaced drains, but 4 years after installation, the yields are more or less similar without significant variations and also little variation in soil salinity. There was no significant difference among CPVC and SW pipe drain areas in controlling salinity and improving the crops yields.

Drainage flow and salts leached

Measurement of drain discharge and discharged water salinity revealed that salts @ 7.3 t/ha were leached during the 1st year of operation of subsurface drainage system, which gradually reduced to 1.87 t/ha during 2007-08. In the year 2008-09, 2.75 t/ha of salts were removed. The total amount of salts leached since installation of the system for last 7 years was 185.43 t/ha over an area of 7.5 ha with an average of 3.53 t/ha/annum (Table 135 and Fig. 42). The ionic composition of drainage effluent revealed that sodium was dominant cation followed by calcium, magnesium and potassium. Amongst the cations, chloride was dominant anion followed by sulphates, bicarbonates and carbonates. The SAR <10 showed that reuse of drainage water might not pose any problem on this account.

In order to know the exact quantum of nutrient losses, the loss of nutrients through drainage was estimated. The total loss of N, P and K was 41.3, 15.0 and 57.6 kg/ha respectively during seven years after installation of the system. Thus, NPK lost through leachate from the influence area was to the extent of 5.9, 2.0, 8.2 kg/ha/annum respectively. The loss of N was higher at paddy transplanting

stage, maximum tillering stage and at panicle initiation stage, which coincided with top dressing of inorganic nitrogenous fertilizers. The loss of P was uniform throughout the crop season while loss of K was higher immediately after planting and at panicle initiation stage. This matches quite well with the application schedule of nutrients to rice crop, which was fertilized with NPK @ 120:60:40 kg/ha respectively. Nitrogen was applied in three equal splits at basal, maximum tillering and panicle initiation (PI) stage while entire P was applied as basal and K was applied in two equal splits at basal and PI stage.

Table 135. Quantity of water, salts and nutrients pumped from SSD system

Year	Volume of water pumped (m^3)	Total salts leached (tons)	Nutrient loss (kg/ha)		
			N	P	K
2002–2003	27448	54.50	79.0	33.0	145.0
2003–2004	19377	27.50	40.0	22.0	84.0
2004–2005	27327	29.90	63.0	17.0	64.0
2005–2006	26784	24.00	23.0	13.0	44.0
2006-2007	14374	14.92	72.0	17.3	29.0
2007–2008	10494	14.00	12.5	1.7	25.0
2008-2009	9723	20.61	20.0	8.6	41.0
Total for 7.5 ha	135527	185.43	309.5	112.6	432.0
Per ha/7 years	18070	24.70	41.3	15.0	57.6
Per ha/annum	2581	3.53	5.9	2.0	8.2

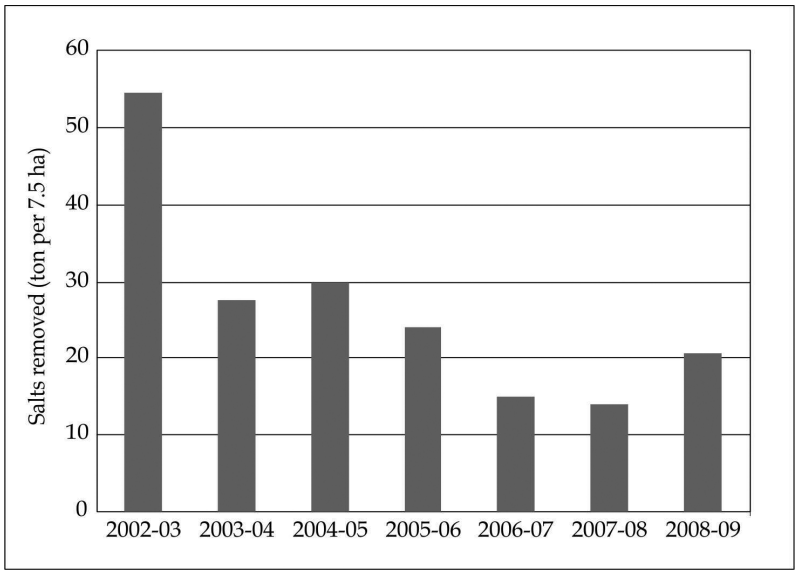


Fig. 42. Quantities of salts removed through pipe drainage system at Appikatla

Changes in soil EC_e

The salt removed through drainage water was reflected in the reduction in soil salinity in treated plots. The soil data revealed that EC_e of soil decreased from an initial mean value of 16.2 to 7.6 dS/m by the end of first year and further reduced to 4.6 dS/m in surface soil of 0-20 cm depth by the end of second year. Finally it was 2.6 dS/m at the end of seven years (Fig. 43).

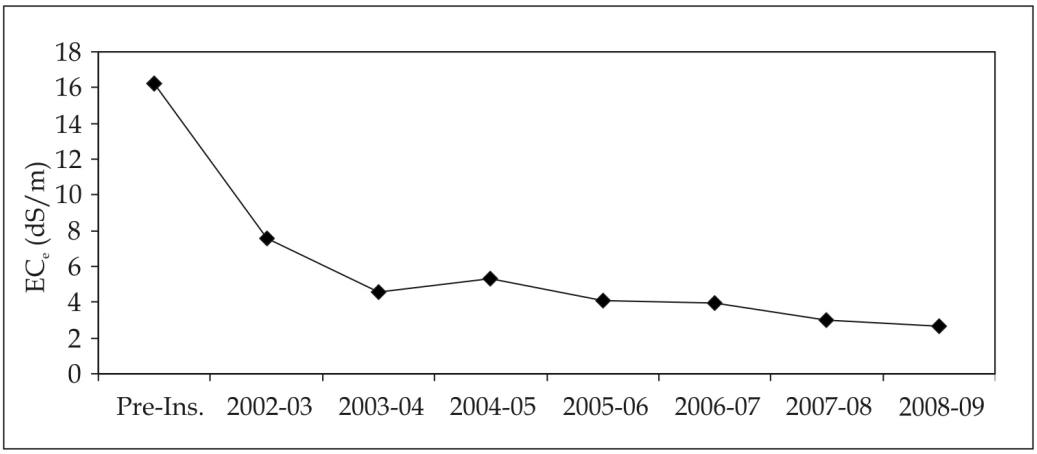


Fig. 43. Changes in soil salinity (EC_e) before and after installation of subsurface drainage

Rice crop yield

Crop cutting data on grain and straw yields revealed that on an average, grain yield of 1.8 t/ha during pre–installation increased to 4.1 t/ha in the first year itself and steadily increased to 6.75 t/ha at the end of 7 years showing an improvement of 73% increase in grain yield with introduction of SSD system (Fig. 44). Also more than 3 fold increase in straw yield was observed.

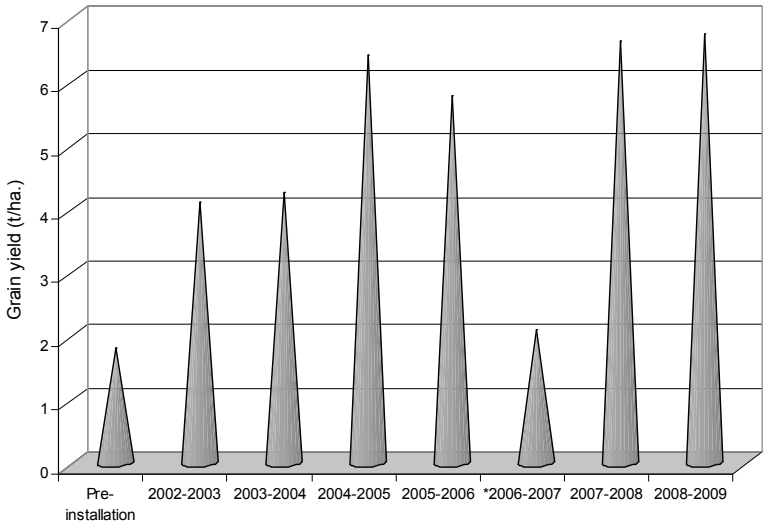


Fig. 44. Effect of subsurface drainage system on grain yield of rice

Investments and economic analysis

Drainage installation costs varied with drain material as well as with drain spacing**.** The cost of 60 m spaced CPVC drains is about 40% less as compared to 30 m spaced drains. Moreover, the cost of stoneware pipe drains is 80-85% of that of CPVC pipe drains. The economic analysis under mono-crop system revealed that the net present worth of the system is Rs. 71106, B-C ratio is 1.24 and internal rate of return 39.07 per cent. Although, subsequently yields further improved and second crop could also be established, these facts were not considered in the analysis resulting in underestimate of the NPV, B-C ratio and IRR. Net annual additional benefits of Rs. 111287 against installation cost of SSD project (7.5 ha) at Rs. 202500 revealed that the total investments made on drainage could be recovered within 2 years, which is similar to the earlier findings that the pay-back period for drainage is about 2-3 years. The project has since been concluded as all the objectives have been met with.

Monitoring Salinity Hazards in Vegetable Crops under Drip Fertigation with Marginally Saline Water in Vertisols – Indore

The study was carried out during 2008-10 to monitor the effect of drip fertigation with marginally saline well water on salinity and economics of horticultural crops grown in Vertisols at farmer's field of Bagda khurd village of Bedia tehsil, Khargone district, Madhya Pradesh. The soils of study area are classified as fine montmorillonitic hyperthermic family of typic haplusterts with particle size distribution as clay >55%, silt >30% and sand <15%. Study area comes under semi-arid sub-tropic climate with annual rainfall range of 600-800 mm. Farmer grew tomato, bitter gourd, garlic during 2008-09 and tomato and bitter gourd during 2009-10. The crops were planted on ridges with recommended package of practices. Periodically soil samples were taken at an interval of 15 days for all the crops at sampling points viz., on drippers, between two consecutive drippers, 15 cm away from dripper (side of dripper) and 30 cm away from dripper (Side of the ridge) at 0-5 cm, 5-15 cm and 15-30 cm. The samples were analyzed for pH and EC. Well water used for irrigation was marginally saline with EC of 0.92 and 1.15 dS/m (Table 136). To work out economics of growing different crops, information on marketable yield, cost of cultivation including drip installation cost and prevailing market rates were collected.

Table 136. Quality parameters of well waters used for irrigation

Parameters	Results	
	Well 1	Well 2
pH	8.16	8.01
EC (dS/m)	0.95	1.15
Calcium (meq/l)	6.60	8.00
Magnesium (meq/l)	1.40	1.80
Sodium (meq/l)	1.33	1.62
Potassium (meq/l)	0.02	0.00
Carbonate (meq/l)	0.20	0.00
Bicarbonate (meq/l)	5.60	6.80
Chloride (meq/l)	2.40	3.40
Sulphate (meq/l)	1.00	0.94
RSC (meq/l)	Nil	Nil
SAR $(mmol/l)^{1/2}$	0.66	1.14

Among the various crops grown by the farmer the details of results of one of the Tomato (Abhinav) crop are discussed as sample example. Similar procedure was followed for other crops grown and abstracted results are included.

Tomato (Abhinav)

Tomato (Abhinav) was sown on 15th of November 2009 in 0.6 ha area. The data indicated that EC increased with number of irrigations except at 6th irrigation when it was flood irrigated (Table 137). Maximum EC was observed at sampling point between drippers followed by side of the ridge. The minimum values were recorded at drippers. Average values of EC were 0.40, 0.46, 0.55, 0.64, 0.0.69 and 0.35 dS/m in case of on drippers sampling point for 1st, 2nd , 3rd , 4th , 5th , and 6th sampling respectively. EC increased as one moved away from the drippers i.e. side of the ridge and between drippers.

Economics

Area distribution, along with marketable yield, yield per ha and wholesale rate of tomato crop are shown in Table 138. The crop wise cost of production as per actual, gross return and calculated B:C

ratio are shown in Table 139. The B:C ratio of tomato came around 2.15 indicating that growing tomato with drip fertigation in black soils is an economically viable venture.

Table 137. EC (dS/m) variation in tomato at various sampling locations (2010)

Sampling point	Depth (cm)	1st EC	2nd EC	3rd EC	4th EC	5th EC	6th EC
On dripper	0-5	0.33	0.44	0.56	0.71	0.70	0.29
	5-15	0.48	0.48	0.57	0.62	0.73	0.38
	15-30	0.38	0.46	0.53	0.59	0.63	0.38
Average	-	0.40	0.46	0.55	0.64	0.69	0.35
Between drippers	0-5	0.78	0.96	1.11	1.16	1.21	0.58
	5-15	0.35	0.45	0.51	0.74	0.18	0.41
	15-30	0.32	0.43	0.69	0.78	0.49	0.53
Average	-	0.48	0.61	0.77	0.89	0.63	0.51
Side of ridge	0-5	0.39	0.56	0.76	0.89	1.09	0.47
	5-15	0.47	0.54	0.66	0.78	0.86	0.56
	15-30	0.40	0.57	0.61	0.74	0.81	0.64
Average	-	0.42	0.56	0.68	0.80	0.92	0.56
Side of drip	0-5	0.43	0.51	0.75	0.88	0.91	0.53
	5-15	0.42	0.48	0.58	0.66	0.76	0.59
	15-30	0.42	0.49	0.61	0.73	0.89	0.67
Average	-	0.42	0.49	0.65	0.76	0.85	0.60

Table 138. Area and yield of tomato under drip fertigation with marginally saline well water

Crop	Area (ha)	Marketable yield (ton)	Yield (t/ha)	Wholesale rate (Rs./ton)
Tomato	0.6	24.6	41	5000

Table 139. Economic analysis of tomato under drip fertigation with marginally saline well water

Crop	Cost of production (Rs./ha)	Gross return (Rs./ha)	Net return (Rs/ha)	B:C ratio
Tomato	95000	205000	110000	2.15

The water use efficiency was obtained as 4.10 q/ha-cm (Table 140).

Table 140. Water use efficiency along with B:C ratio of Tomato grown under drip fertigation with marginally saline well water

Crop	Water applied (cm/ha)	Yield (q/ha)	WUE (q/ha-cm)
Tomato	100	410	4.10

Other crops vis-a-vis tomato

The water use efficiency worked out for different crops are shown in Table 141. The highest WUE was obtained as 5.47 q /ha/cm in case of tomato crop with B:C ratio 2.15 and lowest was with the garlic crop as 2.37 q/ha/cm. The highest B:C ratio of 3.50 was obtained in garlic crop followed by bitter gourd as 3.11. The lowest was in case of tomato as 2.16. B:C ratio is more than one in all the crops grown which implied that drip fertigation with marginally saline well water for cost intensive

cultivation of horticultural crops in Vertisols under sub tropic semi-arid climate is a feasible and economically viable proposition.

Table 141. Water use efficiency along with B:C ratio of various vegetable crops grown under drip fertigation with marginally saline well water

Crops	Water applied (cm/ha)	Yield (q/ha)	WUE (q/ha-cm)	B:C ratio
Bitter gourd	120	350	2.92	3.11
Tomato	075	410	5.47	2.16
Garlic	076	180	2.37	3.50

Effect of Doses and Frequency of Gypsum Application on Soil Properties and Crop Performance in Sodic Soil on Long-Term Basis - Indore

The ESP of experimental soil was around 50 at the time of start. Gypsum was applied as per treatment on the basis of laboratory estimated gypsum requirement in the month of May 2005 and later as per pre-decided doses.

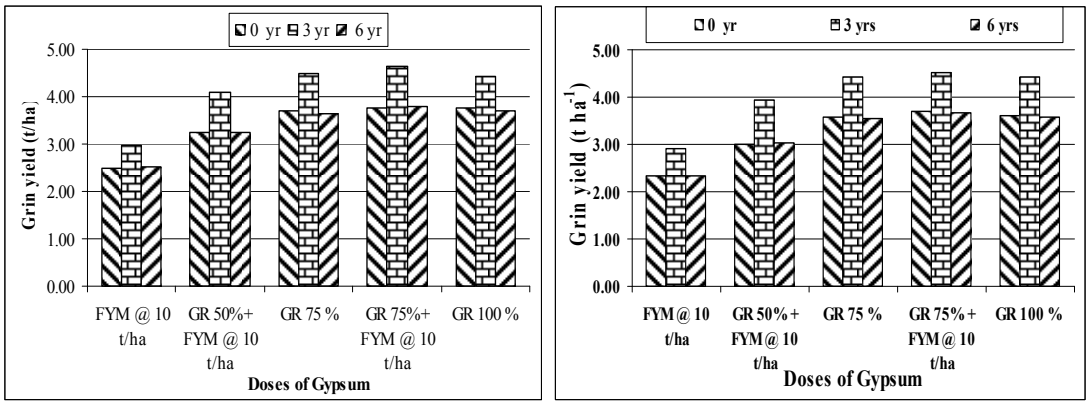
The data in Table 142 revealed that grain yield of paddy increased significantly with doses and frequency of gypsum application. However, interactions of doses and frequency were non-significant w.r.t. grain yield of paddy. The maximum grain yield of paddy (2.17 and 2.13 t/ha) was recorded during the year 2008-09 and 2009-10 respectively, when gypsum was reapplied after 3 years @ 75% GR along with FYM @ 5 t/ha followed by gypsum application @ 75% GR alone. The differences between 75% GR, 75% GR + FYM and 100% GR were non-significant. The treatment of gypsum application in the 6th year has not yet been imposed and as such the yield is not much different than the yield obtained in case gypsum applied once.

Table 142. Effect of frequency and doses of gypsum on grain yield (t/ha) of paddy

Doses of gypsum	Frequency of application				Frequency of application			
	Applied once	Applied twice 3rd year	Applied* thrice 6th year	Mean	Applied once	Applied twice 3rd year	Applied* thrice 6th year	Mean
	2008-09				2009-10			
FYM @ 5 t/ha	1.21	1.46	1.25	1.31	1.25	1.50	1.21	1.32
GR 50%+ FYM @ 5 t/ha	1.58	1.83	1.54	1.65	1.52	1.88	1.42	1.60
GR 75%	1.63	2.13	1.58	1.78	1.63	2.00	1.46	1.69
GR 75%+ FYM @ 5 t/ha	1.67	2.17	1.63	1.82	1.78	2.13	1.75	1.89
GR 100%	1.71	2.04	1.67	1.81	1.67	2.00	1.63	1.76
Mean	1.56	1.93	1.53		1.57	1.90	1.49	
	Freq.	Doses	F x D	D x F	Freq.	Doses	F x D	D x F
CD (5%)	0.15	0.20	NS	NS	0.09	0.10	NS	NS

** Treatment yet to be implemented*

The data in Fig. 45 revealed that grain and straw yield of wheat increased significantly with doses as well as frequency of gypsum application. However, interaction of doses and frequency were non-significant. The maximum grain yield (4.63 and 4.52 t/ha) of wheat was recorded in the year 2008-09 and 2009-10 respectively, when gypsum was reapplied after 3 years @ 75% GR along with FYM @ 5 t/ha) followed by gypsum application @ 75% GR alone. The differences between 75% GR, 75% GR+FYM and 100% GR were non significant.



2008-09 2009-10

Fig. 45. Effect of frequency and doses of gypsum application on grain yield of wheat

The data in Table 143 indicated that ESP of the soil reduced due to application of gypsum. The minimum ESP was recorded in gypsum application @ 100% GR. Very little difference was noticed in soil ESP between gypsum application @ 75% GR along with FYM @ 5 t/ha and 100% GR.

Table 143. Effect of frequency and doses of gypsum on ESP of soil at harvest of wheat crop

Doses of gypsum	Frequency of gypsum application			
	Applied once	Reapplied after 3 years	Reapplied after 6 years	Mean
FYM @ 5 t/ha	44.8	42.2	45.3	44.1
GR 50%+ FYM @ 5 t/ha	38.4	30.4	39.2	36.0
GR 75%	33.1	27.5	33.8	31.5
GR 75%+ FYM @ 5 t/ha	32.1	26.7	32.4	30.4
GR 100%	30.0	26.0	29.8	28.6
Mean	44.6	38.2	45.1	

Efficacy of Phosphogypsum as an Amendment for Alkali Soil - Kanpur

An experiment was conducted to evaluate the efficiency of phosphor-gypsum with Rice (var. NDR-359) and wheat (var. PBW-343) crops with six treatments replicated four time using RBD design at Crop Research Station, Nawabganj, Kanpur. Fertilizer were applied to both the crops in the ratio of 120:60:60 ($N:P_2O_5:K_2O$) kg/ha. Before the start of experiment the soil was analyzed and data showed that soil was having the pH_s 9.45 EC_e 3.5 dS/m, ESP 59.8, organic carbon 0.11 per cent, gypsum requirement is 12.7 t/ha and having sandy loam texture (Table 144).

Table 144. Gypsum and phosphogypsum dissolutions by irrigation water through bed (15 cm)

Year	Treatments	Kharif (t/ha)	Rabi (t/ha)	Total (t/ha)	Cumulative (t/ha)
2009-10	Gypsum	0.51	0.85	1.36 (10.7)	1.36 (10.7)
	Phosphogypsum	0.57	0.95	1.52 (11.9)	2.62 (11.9)

During 2009-10, the yield data of both crops showed an increase in yield with the use of amendment over untreated plots (control). The highest grain yield of rice and wheat was recorded 3.53 and 3.15 t/ha with the application of phosphogypsum which is 4.77 and 4.69 percent higher in comparison to gypsum respectively. The crop irrigated with RSC water through 15 cm gypsum/phosphogypsum found superior than the soil application of amendments (Table 145).

Table 145. Effect of different treatments on yield of crops (t/ha)

Treatments	Rice (2009)	Wheat (2009-10)
T_1	3.02	2.62
T_2	3.27	2.84
T_3	3.64	3.28
T_4	3.43	3.01
T_5	3.46	3.16
T_6	3.28	2.86
CD (5%)	0.17	0.18

T_1: RSCW (Untreated); T_2: BAW; T_3: RSCW (15 cm phosphogypsum bed); T_4 : Soil application of phosphogypsum (equal amount as in T_3); T_5: RSCW (15 cm gypsum bed); T_6 : Soil application of gypsum (equal amount as in T_5)

The physico-chemical properties of soil (pH_s, EC_e and ESP) showed considerable improvement under gypsum amended water passed through gypsum/phosphogypsum bed. There was remarkable change in soil pH (Table 146). The maximum soil pH (9.43) was recorded in RSC treated plots followed by BAW treated (9.37). Dissolution of gypsum and phosphogypsum bed reduced soil pH in the range 9.22-9.23 and 9.15-9.20 respectively. The value of EC_e was maximum (3.52 dS/m) in RSC treated plots followed by BAW, gypsum and phosphogypsum application. The average ESP value in RSC treated plots remained highest (60.0) followed by BAW (57.0), gypsum dissolution (51.1) and phosphor-gypsum (50.0).

Table 146. Effect of treatments on physico-chemical properties of soil (After rice and wheat crop)

Treatments	Depth (cm)	After rice			After wheat		
		pH	EC (dS/m)	ESP	pH	EC (dS/m)	ESP
T_1	00-20	9.43	3.53	60.0	9.42	3.51	59.8
	20-40	9.37	3.51	59.1	9.36	3.50	58.5
T_2	00-20	9.39	3.48	57.0	9.35	3.45	56.5
	20-40	9.37	3.55	56.2	9.32	3.48	55.0
T_3	00-20	9.20	3.30	48.2	9.15	3.20	45.0
	20-40	9.10	3.26	47.0	9.05	3.17	44.2
T_4	00-20	9.26	3.35	50.0	9.20	3.26	48.0
	20-40	9.16	3.25	49.3	9.10	3.15	45.5
T_5	00-20	9.23	3.26	50.5	9.22	3.25	46.3
	20-40	9.15	3.30	50.0	9.14	3.39	42.0
T_6	00-20	9.28	3.37	51.1	9.20	3.32	49.0
	20-40	9.20	3.39	49.3	9.11	3.28	47.8

Notations are same as given in the Table 145

RSC water (8.82 to 8.94 meq/l) when passed through 15 cm gypsum or phosphogypsum bed showed reduction in RSC values and changes in ionic composition (Table 147). No significant changes in pH_{iw} values and in other parameters except Ca+Mg were observed but salt concentration (EC_{iw}) slightly increased. Initial average RSC value (8.71) reduced to 4.22 and 4.06 meq/l in *kharif* 2009 and 4.22 and 4.13 meq/l in 2009-10 and *rabi* 2008-09 by using gypsum and phosphor-gypsum respectively.

Table 147. Change in ionic composition of RSC irrigated water as a result of gypsum and phosphogypsum bed treatment

Treatments	pH	EC (dS/m)	Anions(meq/l)				Cations (meq/l)		RSC (meq/l)
			CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na+K	
RSC^1	8.1	1.2	nil	10.6	0.6	0.5	1.7	10.0	8.7
RSC^2	7.8	1.5	nil	10.3	1.1	3.7	6.0	9.1	4.2
RSC^3	7.8	1.3	nil	10.2	1.1	3.8	6.1	9.1	4.1
BAW	7.5	0.7	nil	4.1	3.3	0.1	6.4	1.0	nil

RSC^1(untreated); RSC^2 (treated with gypsum); RSC^3 (treated with phosphogypsum)

Effect of Management Practices on Resodification of Reclaimed Sodic Lands at Benchmark Sites – Kanpur

Eight benchmark sites, four each representing good and poorly managed reclaimed sodic lands (farmers field) were identified (Table 148) and soil samples at different depths (0-20, 20-40, 40-60, 60-90, 90-120 and 120-150 cm) collected from each benchmark sites during the month of April-May 2010 for analysis and to evaluate the cause of resodification. The analyses of soil sample are in progress.

Table 148. Details of benchmark sites of district Ramabai Nagar and Kanpur

S.N.	Farmer's name	Village	Crops	Water source and management
1.	Deep Narain	Vinovanager	Paddy, wheat, mustard and GM	TW, Good
2.	Suresh	Vinovanager	Paddy, wheat, potato and GM	TW, Good
3.	Indra Jeet	Vinovanager	Paddy and wheat	TW, Poor
4.	Vijay Bahadur	Vinovanager	Paddy and wheat	TW, Poor
5.	Mool Chandra	Migha Nabada	Paddy, potato, wheat and GM	TW, Good
6.	Radhey Lal	Migha Nabada	Paddy, potato, wheat and GM	TW, Good
7.	Pushpendra	Migha Nabada	Paddy and wheat	TW, Poor
8.	Ram Narain	Migha Nabada	Paddy and wheat	TW, Poor

Evaluation of Integrated Resource Conservation Technology for Rice-Wheat Cropping System under Reclaimed Sodic Soil - Kanpur

An experiment was conducted at NARP Research Farm, Kanpur to evaluate the resource conservation technologies in sodic soils. The initial pH, EC_e and ESP of soil were 8.7, 2.6 dS/m and 25 respectively.

In *kharif* 2010 after first year of experimentation, the highest yield of rice grain (3.63 t/ha) and straw (4.47 t/ha) with conventional rice transplanting after *sesbania* green manuring was obtained. (Table 149). The conventional rice transplanting and conventional rice transplanting after wheat residue incorporation and direct seeding rice + *sesbania* were at par with respect to yield. The minimum yield was obtained from direct seeded rice in zero tillage planting method.

Table 149. Effect of treatments on yield of rice (t/ha)

Treatments*	Rice (2010)	
	Grain	Straw
T_1 : Conventional rice transplanting/conventional wheat sowing	3.42	4.17
T_2 : Conventional rice transplanting after WRI (wheat residue incorporation)/conventional wheat sowing after RRI (Rice residue incorporation)	3.43	4.18
T_3 : Direct seeded rice/wheat in reduced tillage	3.23	3.93
T_4 : Direct seeded rice after WRI/wheat in reduced tillage after RRI	3.24	3.95
T_5 : Direct seeded rice/wheat in zero tillage	3.23	3.93
T_6 : Direct seeded rice in zero tillage/wheat in zero tillage	3.11	3.80
T_7 : Direct seeded rice in zero tillage after WRI/ wheat in zero tillage	3.13	3.83
T_8 : Direct seeded rice+sesbania / wheat in zero tillage	3.40	4.17
T_9 : Conservational rice transplanting after sesbania green manuring / wheat in zero tillage	3.64	4.47
CD (5%)	0.25	0.30

**Treatment details as given in text*

C. ALTERNATE LAND MANAGEMENT

- Performance of Ber (*Zizyphus Jujuba*) to different Irrigation Schedules with Saline Water under Mulched Condition using Drip Irrigation (Bikaner)
- Tolerance of Fruit Trees to Saline Irrigation under Drip and Surface Irrigation System (Agra)
- Effect of different Methods of Irrigation and Quality of Water on Performance of Fruit Trees in Sodic Environment (Indore)
- Evaluation of the Performance of Medicinal and Aromatic Plants in Saline Vertisols (Gangawati)
- Influence of different ESP Levels on Performance, Nutrient Uptake and Active Ingredient of Medicinal Plants in Sodic Vertisols (Indore)
- Integrated Farming System Suitable for Problem Soil Areas of Tamil Nadu (Trichy)
- Evaluation of *Jatropha Curcas* in Alkali Soils under Irrigated Condition (Trichy)
- Effect of Salinity on Growth and Yield of Medicinal Plants (Bapatla)

Performance of Ber (*Zizyphus Jujuba*) to different Irrigation Schedules with Saline Water under Mulched Condition using Drip Irrigation – Bikaner

An experiment on assessing the performance of ber with saline water using drip irrigation was started in September 2002. Yield and yield attributes were recorded during 2005-06 to 2008-09. The maximum average yield (43.6 kg/plant) was obtained in treatment 0.8 PET + plastic mulch with BAW. Even under saline water this treatment resulted in maximum yield (39.6 kg/plant). The average fruit diameter varied from 2.84 to 3.77 cm in different treatments, highest being in 0.8 PET + mulch and lowest in 1.0 PET BAW without mulch. Similar trend was also observed in case of average weight of 10 fruits (Table 150). Further, no significant difference was observed in yield levels for saline and BAW both under mulched and unmulched conditions. It can be inferred that saline water upto 8.0 dS/m can be successfully used for ber cultivation under drip irrigation without any significant reduction in yield.

Table 150. Weight, average diameter and fruit/plant as affected by different treatments

Treatment	Average weight of fruits (g)					Average diameter (cm)					Fruit yield/plant (kg)				
	05-06	06-07	07-08	08-09	Mean	05-06	06-07	07-08	08-09	Mean	05-06	06-07	07-08	08-09	Mean
1.0 BAW	29.0	30.7	28.1	30.3	29.5	2.71	2.84	2.92	2.91	2.84	27.90	28.12	32.47	31.2	29.9
0.8 BAW	33.0	34.3	32.9	34.1	33.6	3.51	3.72	3.45	3.60	3.57	31.10	34.93	44.18	42.9	38.3
1.0 Saline	27.5	29.1	30.1	28.7	28.8	2.60	2.71	3.27	2.97	2.89	26.40	27.00	41.20	33.7	32.1
0.8 Saline	31.0	32.8	35.3	34.4	33.4	3.40	3.60	3.90	3.70	3.65	30.40	32.16	49.97	41.2	38.4
1.0 BAW + M	30.5	32.3	26.3	30.7	29.9	3.10	3.30	2.77	3.02	3.05	30.00	31.63	39.44	37.3	34.6
0.8 BAW + M	37.5	39.7	32.8	37.0	36.7	3.90	4.01	3.37	3.79	3.77	35.87	39.49	46.80	52.2	43.6
1.0 Saline + M	30.0	31.8	29.9	31.5	30.8	2.83	2.94	3.27	2.93	2.99	28.70	29.86	39.39	35.3	33.6
0.8 Saline + M	34.5	36.5	35.0	35.1	35.3	3.65	3.84	3.73	3.81	3.76	32.63	38.17	43.30	44.5	39.6
S.Em	1.5	1.3	1.2	0.8		0.16	0.18	0.20	0.13		1.4	1.7	1.3	3.2	
CD (5%)	4.7	3.8	3.6	2.4		0.50	0.54	0.61	0.39		4.3	5.1	3.9	9.6	

Saline water EC_{iw} : 8.0 dS/m

The total water applied to the crop is presented in Table 151. The total water required in the crop season was 8780 and 7024 litres at 1.0 PET and 0.8 PET respectively during 2008-09 whereas corresponding values for the year 2005-06 to 2008-09 were 8655 and 6927 litres at 1.0 PET and 0.8 PET, respectively.

Table 151. Total water applied to ber (litres/month/plant)

Month	2005-06		2006-07		2007-08		2008-09		Average	
	1.0 PET	0.8 PET	1.0 PET	0.8 PET	1.0 PET	0.8 PET	1.0 PET	0.8 PET	1.0 PET	0.8 PET
May	1581	1265	1516	1213	1881	1506	1748	1378	1681	1340
June	1422	1138	1506	1205	1946	1548	1779	1418	1663	1327
July	1135	900	1128	903	1508	1237	1243	994	1253	1008
August	1004	804	967	774	1328	1062	1116	893	1104	883
September	810	648	732	586	1085	867	979	783	901	721
October	725	580	660	528	851	679	670	536	726	581
November	576	461	486	389	512	408	573	459	537	429
December	561	449	453	362	348	276	322	258	421	336
January	384	308	350	280	387	307	350	280	368	294
Total	8198	6553	7798	6240	9846	7890	8780	7024	8655	6927

The distribution of salts in the soil profile at harvest stage during 2008-09 indicated that application of saline water resulted in accumulation of salts in the lower depth of the soil profile (Table 152). The salts leached from the upper layers are being piled up in the lower depths. Comparatively, high salinity levels existed in treatments with 0.8 PET without mulch conditions at almost every point of observation. This could be attributed to lower moisture levels in soil profile as compared to 1.0 PET, thereby, increasing the salinity status.

Table 152. Salinity (EC_e) distribution in soil profile under drip for ber with EC_{iw} 8 dS/m (2008-09)

Distance from emitter (cm)	Soil depth	1.0 WR	0.8 WR	1.0 WR + M	0.8 WR + M
15	0-15	2.28	2.00	2.02	1.83
	15-45	2.68	2.46	2.22	2.33
	45-75	2.80	2.71	2.61	2.56
	75-105	3.42	3.26	2.95	2.91
30	0-15	2.88	2.50	2.53	2.28
	15-45	3.06	3.09	2.88	2.81
	45-75	3.36	3.25	3.17	3.00
	75-105	3.14	3.30	2.97	2.91
60	0-15	3.01	2.89	2.69	2.50
	15-45	3.38	3.31	3.08	2.91
	45-75	3.68	3.49	3.47	2.98
	75-105	3.44	3.51	3.34	3.21
90	0-15	3.35	3.09	2.91	2.52
	15-45	3.95	3.67	3.44	2.78
	45-75	3.97	3.04	3.68	3.59
	75-105	3.97	3.59	3.96	3.75

During 2009-10, the treatments were modified by incorporating three levels of irrigation i.e. 0.4 PET, 0.6 PET and 0.8 PET. The maximum average yield (55.93 kg/plant) was obtained in treatment 0.6 PE. Even under saline conditions this treatment recorded maximum yield (47.30 kg/plant). The average fruit diameter varied from 2.79 to 3.80 in different treatments being highest in 0.6 PE. Similar trend was observed in case of average weight of 10 fruits (Table 153). Significantly higher yield was obtained at 0.6 PET than 0.4 PET for both saline and best available water. Yields were at par for 0.8 PET and 0.6 PET for both saline and fresh water.

Table 153. Weight, average diameter and fruit/plant of ber under different treatments

Treatments	Weight of 10 fruits (g)	Av. diameter (cm)	Fruit yield/plant (kg)
0.8 BAW	329	3.51	49.67
0.6 BAW	379	3.80	55.93
0.4 BAW	297	2.97	39.66
0.8 Saline	304	3.70	45.20
0.6 Saline	310	3.72	47.30
0.4 Saline	268	2.79	34.21
S.Em ±	7.8	0.13	3.17
CD (5%)	23.6	0.39	9.60

Perusal of data on distribution of salts in soil profile at harvesting stage (Table 154) revealed that application of saline water resulted in the accumulation of salts in lower soil profile. Higher salt concentration was observed at increasing distance from plant both laterally and vertically downwards.

Table 154. Salinity (EC_e) distribution in soil profile under drip for ber with EC_{iw} 8.0 dS/m (2009-10)

Distance from emitter (cm)	Soil depth (cm)	0.8 PET	0.6 PET	0.4 PET
15	0-15	2.61	2.52	2.53
	15-45	2.73	2.69	2.88
	45-75	2.69	2.73	3.17
	75-105	2.94	2.98	2.97
30	0-15	2.63	2.93	2.53
	15-45	2.84	2.98	2.69
	45-75	2.92	2.83	2.61
	75-105	3.01	2.97	2.95
60	0-15	2.79	3.00	2.69
	15-45	3.01	3.11	3.08
	45-75	3.32	3.17	3.47
	75-105	3.37	3.27	3.34
90	0-15	2.90	3.11	2.91
	15-45	3.31	2.98	3.44
	45-75	3.21	3.27	3.68
	75-105	3.62	3.82	3.96

Tolerance of Fruit Trees to Saline Irrigation under Drip and Surface Irrigation System - Agra

A field experiment was initiated during 2003 to assess the salinity tolerance of guava and pomegranate. The treatments were two irrigation systems, drip and surface irrigation, three salinity levels: BAW, 8 and 12 dS/m and three IW/CPE ratios: 0.5, 0.75 and 1.0. In case of pomegranate the survival was 100% after fours of year experimentation. The fruit yield of pomegranate was found to decline with salinity of irrigation water in both irrigation methods. The pooled yield of three years under drip system was significantly higher (11.2%) as compared to surface irrigation. The salinity levels also showed significant effect on yield. The yield in BAW and EC_{iw} 8 did not differ significantly but in 12 EC_{iw} decline in the yield was by 37.5% as compared to BAW. The highest yield was recorded with ET 1.0. The yield decreased by 12.3 and 29.5% in ET 0.75 and 0.5 respectively (Table 155).

Table 155. Effect of various treatments on yield attributes and yield of pomegranate (Av. 2006-09)

Treatments		No. of fruit/plant	Diameter/fruit (cm)	Fruit yield (kg/plant)	Fruit yield (t/ha)
Method of irrigation	Surface	42.5	17.3	14.5	11.8
	Drip	48.6	18.1	15.9	13.3
	CD (5%)	1.3	0.5	0.2	0.4
Salinity levels	BAW	49.8	18.6	16.9	14.4
	8 dS/m	50.2	18.3	16.6	13.6
	12 dS/m	36.5	15.6	12.4	9.0
	CD (5%)	1.4	0.5	0.5	0.9
ET	0.50	41.2	16.5	13.2	10.3
	0.75	46.7	17.4	15.3	12.8
	1.00	48.7	18.7	16.5	14.6
CD (5%)		1.2	0.6	0.5	0.3
Method x EC_{iw}		1.8	NS	0.5	0.5
Method x ET		NS	0.5	NS	0.4
EC_{iw} x ET		1.7	NS	0.5	0.6
Method x EC_{iw} x ET		NS	NS	1.2	NS

The soil salinity was monitored during February and June in surface irrigation system (Table 156). In February EC_e was maximum in ET 1.0 at all salinity levels as compared to ET 0.5. In the month of June (pooled basis), due to rainfall at the time of sampling the soil salinity decreased in upper layers (0-15cm) and increased in lower layers

In drip irrigation system minimum EC_e was recorded in ET 1.0 with EC_{iw} 12 dS/m at l 45 cm distance away from the tree, EC_e was less in 0-15 cm depth and higher in other lower layers during June i.e. 5.2 to 5.8 in BAW, 11.5 to 13.4 EC_{iw} 8 and 15.1 to 18.3 dS/m in EC_{iw}12 in ET 0.5 and ET 1.0. The EC_e was higher in whole profile under ET 1.0 as compared to ET 0.5.

Table 156. Effect of different treatments on soil salinity

Treatments	Depth (cm)	Surface		Drip					
		February	June	February			June		
				15 cm	30 cm	45 cm	15 cm	30 cm	45 cm
Best Available Water									
0.5 ET	0-15	4.5	5.2	4.4	4.5	4.5	4.6	5.2	5.2
	15-30	4.3	5.1	4.2	4.2	4.4	4.8	5.3	5.5
1.0 ET	0-15	4.9	5.7	4.8	4.8	5.1	5.1	5.1	5.8
	15-30	4.7	5.3	4.7	4.7	5.0	5.6	5.7	5.7
Salinity of Irrigation Water (EC_{iw} 8 dS/m)									
0.5 ET	0-15	8.5	11.3	8.2	8.7	9.8	10.4	10.7	11.5
	15-30	8.0	10.1	8.7	9.4	10.1	11.6	11.1	12.1
1.0 ET	0-15	9.2	12.2	9.5	10.1	10.8	12.1	12.8	13.4
	15-30	8.8	12.8	10.1	10.8	11.3	12.6	13.6	14.2
Salinity of Irrigation Water (EC_{iw} 12 dS/m)									
0.5 ET	0-15	11.1	14.8	10.5	11.2	11.5	13.1	13.3	15.1
	15-30	11.2	15.9	10.6	11.1	11.1	14.8	14.5	15.7
1.0 ET	0-15	11.6	20.1	11.8	12.2	12.2	14.7	17.8	18.3
	15-30	11.1	19.2	12.1	12.8	12.5	18.1	18.2	18.8

Effect of different Methods of Irrigation and Quality of Water on Performance of Fruit Trees in Sodic Environment - Indore

The study was carried out in sodic black soils at Barwaha.Three fruit plants viz., Ber (Banarsi Kadka), Sapota (Ganesh) and Pomegranate (Kalipatti) were transplanted in pits of size 45 x 45 x 45 cm filled with excavated soil mixed with gypsum @ 100% GR along with FYM. The normal practice of irrigation (twice in a month) was adopted to irrigate the saplings before irrigation treatments were super imposed. Two different qualities of irrigation waters i.e. Best Available water (BAW) and diluted spent wash were used for irrigation as per treatments. Twelve plants of each fruit plants were irrigated by three irrigation methods and the qualities of irrigation water. The EC, SAR and RSC of normal water were 0.5 dS/m, 1.1 $(mmol/l)^{½}$ and nil respectively. However the EC, SAR and RSC of diluted spent wash (1:30 ratio) were 0.93 dS/m, 7.3 $(mmol/l)^{½}$ and nil respectively. Two bio metric parameters i.e. thickness and height were recorded during the year 2008-09 and 2009-10.

The change in average thickness and height was worked out by considering average thickness and height of plants under each treatment at the time of planting and during the years 2008-09 and 2009-10 (Fig. 46a, b, c, d). Better growth in terms of thickness and height was observed in case of embedded pipe and drip irrigation as compared to check basin in all the fruit plants. The data also revealed that the change in thickness and height was more in case of irrigation by diluted spent wash as compared to irrigation by best available irrigation water.

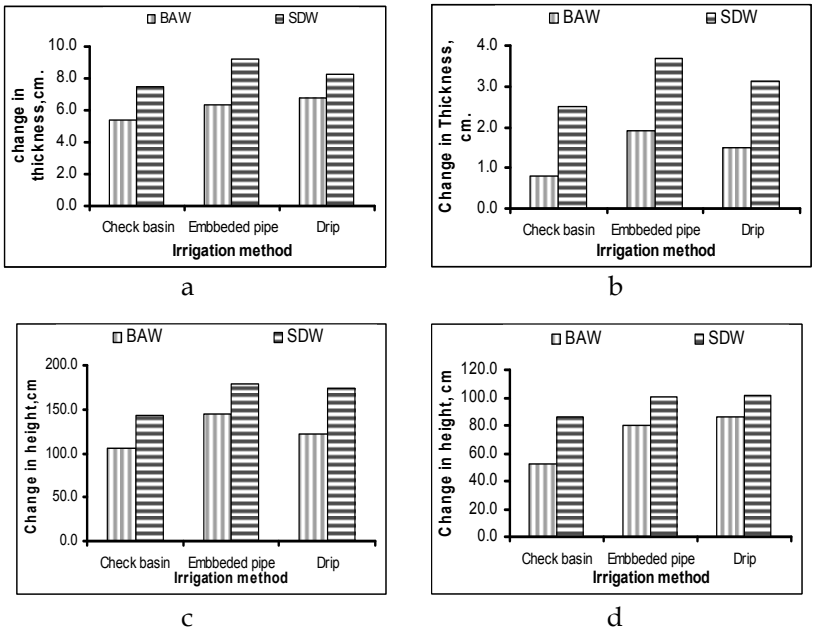


Fig. 46. Comparison of change in thickness and height of plants under different methods of irrigation and quality of water

Study revealed that embedded pipe irrigation method (pipe diameter 100 mm and length 40 cm) is markedly effective and promising in performance as compared to conventional check basin method in terms of saving of irrigation water and improvement in bio-metric parameters.

Evaluation of the Performance of Medicinal and Aromatic Plants in Saline Vertisols - Gangawati

In our earlier attempts to identify suitable crops/cropping sequences for saline Vertisols of TBP irrigation command, economically it was not feasible to replace the existing paddy-paddy which gave highest economic returns. However, in view of increasing shortage of water to sustain this cropping sequence and also increasing problem of water logging and salinity especially in low–lying areas due to paddy-paddy cropping system, a more economic crop/cropping sequence is required to be established to convince the farmers to shift from paddy to other crops with low water requirement. Thus, field experiments with different species of aromatic and medicinal plants are being conducted to their threshold soil salinity levels since 2006.

Field experiments under natural salinity gradient were continued during 2008-09 and 2009-10. During 2008-09, evaluation of performances of Ashwagandha (*Withania somnifera*), Palmarosa (*Cymbopogon martini*), Vetiver (*Vetiveria zizanioides*) and Lemon grass (*Cymbopogon citrates*) were continued. During 2009-10, evaluation of performances of Kamakasturi (*Oscimum bassilicum*), Shatavar (*Asparagus recemosus),* Citronella (*Cymbopogan winterianus*), Kalmegh (*Andrographis paniculata)* and Tulsi (*Ocimum sanctum*) were initiated along with Vetiver (*Vetiveria zizanioides*). Each of these crops was grown in three rows of 5m length in each salinity block along the salinity gradient, which ranged from <2.0 to 16 dS/m. However, due to failure in establishing of Tulsi and Kalmegh respectively, these experiments were discontinued. Soil salinity (0-30 cm depth) in each block of rest of the experiments was estimated by drawing representative samples from all the salinity blocks. The yields of economic parts (seed/foliage/root) of these crops were recorded and oil content of Palmarosa, Vetiver, Lemon grass, Kamakasturi (leaves as well as inflorescence) and citronella in each block was measured. The economic yields of these crops were related to soil salinity using SegReg programme.

The threshold salinity levels (EC_t) and the slope observed for various economical part (s) of different crops is shown in Table 1. During 2008-09, the economic threshold salinity for seed and root yields of ashwagandha was observed to be at EC_t 4.06 dS/m and 3.34 dS/m respectively indicating that root is slightly less tolerant to salinity than the reproductive part i.e., seed, similar to the observations made

during previous years. Though there is variation in the slope, the threshold salinity levels observed in case of palmarosa and lemon grass were almost similar i.e., 4.49 and 4.44 dS/m respectively. Among the crops tested, vetiver was relatively more salt-tolerant with the EC_t value of 6.13 dS/m (2008-09) and 5.99 dS/m (2009-10). During 2009-10, kamaksturi and shatavari recorded EC_t values of 5.38 dS/m and 4.05 dS/m respectively with no threshold break point observed for citronella (Table 157).

Table 157. Economic threshold salinity (EC_t) level of medicinal and aromatic crops

Crop/Economic plant part	2008-09		2009-10	
	Threshold salinity EC_t (dS/m)	Slope when x >BPx (g/unit EC)	Threshold salinity EC_t (dS/m)	Slope when x >BPx (g/unit EC)
Ashwaganda				
Seed	4.06	-222	----	-----
Root	3.34	-120		
Palmarosa (foliage)	4.49	-449	-----	-----
Lemon grass (foliage)	4.44	-2080	-----	-----
Vetiver (root)	6.13	-250	5.99	-144
Kamakasturi (foliage)	-----	-----	5.38	-2330
Citronella (foliage)	-----	-----	No threshold salinity observed	
Shatavar (bulb)	-----	-----	4.05	-5420

As far as per cent oil content and the soil salinity relationship are concerned, as revealed by the R^2 values, there was no good relationship between palmarosa, vetiver, lemon grass, kamakasturi and citronella. However, the oil content appears to remain almost constant as indicated by the trend lines.

Influence of different ESP Levels on Performance, Nutrient Uptake and Active Ingredient of Medicinal Plants in Sodic Vertisols - Indore

A field experiment was conducted on sodic Vertisols at Barwaha with three replications at 25, 35, 45 and 55 ESP, which were created in the past years. The planting of babchi, muskdana and sadabahar was done at the time of onset of monsoon in last week of July in *kharif* season of 2008. Four lines (30 cm apart) of each species were planted in plot size of 3.0 x 1.8 m. The crops were fertilized with recommended dose of fertilizers. Survival per cent was counted at 45 days after planting.

During *rabi* season of 2008-09, another field experiment was conducted in RBD with six replications in a plot size of 3.0 x 1.8 m by cultivating chandrasur and isabgol crops at different ESP levels viz. 25, 35, 45 and 55. The recommended doses of fertilizers were applied before sowing of crops. At harvest seed yield of each crop was recorded.

The data presented in Table 158 showed that the survival per cent of different medicinal plant species decreased with increase in levels of soil ESP. The survival of babchi and sadabahar was more than 50% up to ESP 35 whereas survival of muskdana was <50%. Babchi and sadabahar had 77 and 52% survival at ESP 35 which decreased to 41 and 12 per cent, respectively at ESP 45.

The data on seed yield of isabgol and chandrasur presented in Table 159 indicated that the seed yield of isabgol and chandrasur significantly decreased with increasing levels of ESP. The highest seed yield of Isabgol (0.88 t/ha) and chandrasur (0.99 t/ha) was recorded at ESP 25, the lowest being at ESP 55. The reduction in seed yield of isabgol and chandrasur was more than 50% beyond ESP 35. Both the crops are sensitive to higher levels of soil ESP.

Table 158. Survival (%) of medicinal and aromatic plant species under different ESP levels

Plant species	ESP levels			
	25	35	45	55
Babchi *(Psoralea corylifolea)*	83	77	41	12
Sadabahar *(Catharanthus roseus)*	60	52	12	Nil
Muskdana *(Abelmoschas moschatus)*	40	21	8	Nil

Table 159. Effect of different ESP levels on seed yield (t/ha) of Isabgol and Chandrasur

ESP Levels	Isabgol		Chandrasur	
	Yield	% reduction	Yield	% reduction
25	0.880	-	0.987	-
35	0.555	37	0.678	31
45	0.307	65	0.385	61
55	0.217	75	0.268	72
CD (5%)	0.183		0.146	

Integrated Farming System Suitable for Problem Soil Areas of Tamil Nadu - Tiruchirapalli

An experiment was initiated during September 2009 to evolve a suitable farming system for sustainable income in the problem soil areas. Currently only 3 components are adopted. Cropping (area 0.36 ha); Fisheries (area 0.04 ha) and Poultry (placed over the pond) cover a total area of 0.4 ha (1 acre) (Fig. 47). Details of each component are:

I. Cropping programme

Cropping pattern			Area
Green gram (VBN 2) (Jun – Aug)	Rice (TRY 1) (Sep – Jan)	Maize (COHM 5) (Feb – May)	0.16 ha
Dhaincha (Jul – Aug)	Rice (TRY 1) (Sep – Jan)	Okra (Akra Anamica) (Feb – May)	0.10 ha
Maize (COHM 5) (Jul – Aug)	Rice (TRY 1) (Sep – Jan)	Sesame (TMV 3) (Feb – Apr)	0.10 ha

II. Fisheries

300 fingerlings were released in the fish pond of the following varieties in 4:2:3:1 ratio.

i. Catla / Silver carp (Surface feeder) : 120 (4)

ii. Rohu (Column feeder) : 60 (2)

iii. Mirgal / Common carp (Bottom feeder) : 90 (3)

iv. Grass carp (Grass feeder) : 30 (1)

III. Poultry

To meet the feed requirement of 300 poly culture fingerlings in the fish pond twenty number of pap kok chicks were reared in the poultry shed.

Control

Normal crop rotation followed by the farmer (0.40 ha)

Cropping pattern			Area
Dhaincha (Jul – Aug)	Rice (TRY 1) (Sep – Jan)	Fallow	0.20 ha
- 	Rice (TRY 1) (Sep – Jan)	Cucumber (Co 1) (Feb – May)	0.20 ha

Fig. 47. View of integrated farming system involving fish culture and poultry

The results are being processed and would be presented in the next annual report. Plantation crops on the bunds (dykes) would be introduced later.

Evaluation of *Jatropha Curcas* in Alkali Soils under Irrigated Condition - Tiruchirapalli

An experiment was initiated during October 2008 to develop suitable spacing and amendment for *Jatropha* cultivation in alkali soils. Treatment details are as follows:

Main plot treatment: Spacing (3)
M_1: 2.5 x 2.5 m; M_2: 3.0 x 3.0 m; M_3: 3.5 x 3.5 m
Sub plot treatments: Amendments (5)
S_1: Native soil with phosphogypsum @ 50% GR; S_2: Native soil with DSW @ 150 ml/kg of soil
S_3: Native soil with phosphogypsum @ 25% GR+ DSW @ 75 ml/kg of soil
S_4: Composted coir pith @ 15 t/ha; S_5: No amendment

With the use of tractor driven augerhole, pits of size 30 cm diameter and 60 cm depth were made at the specified spacing as per the treatment. Based on the treatment schedule gypsum was applied @ 180 gm/pit (50% GR), 90 gm/pit (25% GR) and distillery spent wash (DSW) was applied @ 9.0 lit/(150 ml/kg of excavated soil) and 4.5 lit/pit (75 ml/kg of excavated soil). Composted coir pith was applied @ 108 kg/plot (15.0 t/ha). Six months old seedlings were planted in the pits on 31.10.2008.

The observations on crop establishment, plant height and number of branches at the 6th, 9th, 12th and 18th month after planting were recorded. The effect of spacing and amendments on establishment of *Jatropha* seedlings is given in Table 160. Both the spacing and amendment application had no significant effect on establishment of the crop. The biometric observations revealed that the main plot treatments viz., different spacing did not significantly influence the plant height and number of branches of *Jatropha* plant (Table 161 and 162). Among the subplot treatments, spot amelioration with distillery spent wash (DSW) @ 150 ml/kg of excavated soil recorded the maximum plant height of 144.7 cm which was at par with the treatment receiving combined application of DSW (@ 75 m1/kg of excavated soil) and 25% GR (S3) and application of gypsum @ 50% GR (S_2). Lowest plant height was found in no amendment plot (S_5). The interaction between spacing and amendment was not significant. Similarly number of branches/ plant was higher in spot amelioration with distillery spent wash (DSW) @ 150 ml/kg of excavated soil which was at par with the treatment receiving combined application of DSW (@ 75 m1/kg of excavated soil) and 25% GR (S3) and application of gypsum @ 50% GR (S_2).

Table 160. Effect of spacing and amendments on establishment of *Jatropha* seedlings

Spacing	Amendments					
	S_1	S_2	S_3	S_4	S_5	Mean
M_1	76.8	71.8	71.4	89.6	89.6	79.6
M_2	73.8	73.1	78.0	73.8	73.8	74.5
M_3	77.9	81.7	78.0	81.7	90.0	81.8
Mean	75.8	75.6	75.8	81.7	84.3	
CD (5%)	M	S	M at S	S at M		
	NS	NS	NS	NS		

Note: Establishment percentage converted as arc sin value

Table 161. Effect of spacing and amendments on plant height (cm)

6th month

Spacing	Amendments					
	S_1	S_2	S_3	S_4	S_5	Mean
M_1	69.9	73.5	76.6	62.4	57.3	68.0
M_2	72.6	70.9	65.3	57.4	60.4	65.3
M_3	62.7	68.4	65.0	53.8	34.8	56.9
Mean	68.4	70.9	69.0	57.9	50.8	
CD (5%)	M	S	M at S	S at M		
	7.75	12.26	20.43	21.24		
9th month						
M_1	89.7	91.5	94.1	73.1	68.1	83.3
M_2	81.5	86.5	88.0	70.4	64.3	78.1
M_3	72.7	73.5	78.0	68.8	58.7	70.3
Mean	81.3	83.8	85.0	70.8	63.7	
CD (5%)	M	S	M x S	S x M		
	NS	NS	NS	NS		
12th month						
M_1	112	108	96	84	82	96.4
M_2	108	112	98	86	86	98
M_3	116	116	101	91	84	101.6
Mean	112.0	112.0	98.3	87.0	84.0	
CD (5%)	M	S	M x S	S x M		
	5.1	9.8	16.4	17.8		
18th month						
M_1	132	146	141	128	118	133
M_2	136	142	142	126	108	130.8
M_3	133	146	144	131	105	131.8
Mean	133.7	144.7	142.3	128.3	110.3	
CD (5%)	M	S	M at S	S at M		
	NS	6.8	NS	NS		

Table 162. Effect of spacing and amendments on number of branches/plant

9th month

Spacing	Amendments					
	S_1	S_2	S_3	S_4	S_5	Mean
M_1	6.23	6.33	8.33	4.90	4.13	5.98
M_2	5.63	5.77	6.23	4.67	3.90	5.24
M_3	4.70	5.10	5.47	4.33	3.77	4.67
Mean	5.52	5.73	6.68	4.63	3.93	
CD (5%)	M	S	M at S	S at M		
	NS	NS	NS	NS		
18th month						
M_1	7.2	8.8	8.1	6.6	5.8	7.3
M_2	7.6	9.2	7.8	7.2	6.2	7.6
M_3	7.8	8.6	8.4	6.5	5.9	7.44
Mean	7.5	8.9	8.1	6.8	6.0	
CD (5%)	M	S	M at S	S at M		
	NS	0.43	NS	NS		

Effect of Salinity on Growth and Yield of Medicinal Plants - Bapatla

Aloe vera: Field experiment was conducted on a sandy soil whose initial EC was 0.10 dS/m, pH was 8.37, available N was 83.5 kg/ha, available P_2O_5 was 21.4 kg/ha and available K_2O was 203.5 kg/ha with 0.21% organic carbon. The spacing was 1 x 1 m with plot size of 12 sq m. The irrigation treatments were BAW, 2, 4, 6, 8 and 10 dS/m EC_{iw}. The fertilizer dose was 20-20-20 kgs of N-P_2O_5-K_2O /ha. The data on fresh biomass yield of Aloe showed that treatments T_1, T_2, T_3 and T_4 were at par and significantly higher as compared to T_5 and T_6. The salt build-up in soils was very marginal due to saline water irrigations and the change in pH was negligible (Table 163). The fresh biomass yields in 2009-10 were highest with T_1 (25.8 t/ha) followed by T_2 (24.6 t/ha), T_3 (23.5 t/ha), T_4 (23.0 t/ha) which were at par and significantly higher as compared to T_5 and T_6. The salt build-up due to saline irrigations was 0.12 to 1.20 dS/m at T_1 to T_6 as compared to 0.12 dS/m initially. The difference in pH was marginal (Table 164).

Mentha spicata: **(**Mint**)** Pot culture experiment was conducted in sandy loam soil with initial EC 1.15 dS/m, pH 7.9, available N 140 kg/ha, available P_2O_5 24.2 kg/ha, available K_2O 360.5 kg/ha with 0.31% organic carbon. The irrigation treatments were BAW, 2, 4, 6, 8 and 10 dS/m EC_{iw}. The data on fresh leaf yield of mint showed that treatments T_1, T_2, T_3 and T_4 were at par and significantly higher as compared to T_5 and T_6. The salt build-up in soils was very marginal due to saline water irrigations and the change in pH was also marginal (Table 163). In 2009-10 also, the fresh biomass revealed that increased levels of EC_{iw} decreased the yield. Highest yield was recorded with T_1 (373.0 g/pot) while lowest yield was recorded with T_6- 10 EC_{iw}. The salt build-up due to saline irrigations was from 0.40 dS/m at T_1 to 1.36 dS/m with T_6 against 0.40 dS/m initially. The difference in pH was marginal (Table 164).

Solanum nigrum: Pot culture experiment was conducted in sandy loam soil with initial soil EC 1.15 dS/m, pH 7.90, available N 140 kg/ha, available P_2O_5 24.2 kg/ha, available K_2O 360.5 kg/ha with 0.31% organic carbon. The irrigation treatments were BAW, 2, 4, 6, 8 and 10 dS/m EC_{iw}. The data on biomass yield showed that treatments T_1, T_2, T_3 and T_4 were at par and significantly higher over T_5 and T_6. The salt buildup in soils was marginal due to saline water irrigations and the change in pH was also marginal (Table 163). The fresh biomass yield in 2009-10 showed that highest yield of 165 g/pot was recorded with T_1 (BAW) followed by T_2 (135g) >T_3 (130g) >T_4 (117.5g) >T_5 (96.3g) >T_6

(85.0g). The salt build-up due to saline irrigations was from 0.40 at T_1 to 1.56 dS/m at T_6 as against 0.40 dS/m initially. The difference in build-up of pH was marginal (Table 164).

Table 163. Effect of saline water on soil properties and yield of medicinal plants (2008-09)

Treatments	*Aloe vera*			*Mentha spicata*			*Solanum nigrum*		
	EC (dS/m)	pH	Fresh biomass yield (t/ha)	EC (dS/m)	pH	Fresh leaf yield (g/pot)	EC (dS/m)	pH	Biomass yield (g/pot)
EC_{iw} (dS/m)									
T_1-BAW	0.10	8.37	23.76	1.15	7.90	136.2	1.15	7.90	55.80
T_2-2	0.66	8.41	24.00	1.20	7.95	128.7	1.22	7.80	56.48
T_3-4	0.73	8.39	23.50	1.26	7.96	122.0	1.28	7.90	54.65
T_4-6	0.85	8.47	22.46	1.30	7.92	120.0	1.35	7.88	53.58
T_5-8	0.98	8.43	17.60	1.40	7.90	106.2	1.56	7.92	52.00
T_6-10	1.21	8.42	4.80	1.51	7.95	87.5	1.70	7.86	32.53
CD (5%)			1.32			25.2			2.82
CV			4.90			14.4			3.69

Table 164. Effect of saline water on soil properties and yield of medicinal plants (2009-10)

Treatments	*Aloe vera*			*Mentha spicata*			*Solanum nigrum*		
	EC (dS/m)	pH	Fresh biomass yield (t/ha)	EC (dS/m)	pH	Fresh leaf yield (g/pot)	EC (dS/m)	pH	Biomass yield (g/pot)
EC_{iw} (dS/m)									
T_1-BAW	0.12	8.3	25.8	0.40	8.2	373.0	0.40	8.2	165.0
T_2-2	0.64	8.4	24.6	0.50	8.2	341.0	0.80	8.3	135.0
T_3-4	0.72	8.4	23.5	1.00	8.2	273.0	1.10	8.2	130.0
T_4-6	0.84	8.2	23.0	1.25	8.2	220.0	1.25	8.3	117.5
T_5-8	0.96	8.3	20.8	1.28	8.3	126.0	1.34	8.1	96.3
T_6-10	1.20	8.4	9.4	1.36	8.4	70.0	1.56	8.1	85.0
CD (5%)			2.83			21.15			8.73
CV			7.30			6.00			4.77

D. SCREENING OF CROP CULTIVARS AND GENOTYPES

- Screening of Elite Varieties of Crops for Cultivation with Poor Quality Water (Hisar)
- Screening of Mustard Cultivars for Saline Irrigation (Agra/Hisar/Bikaner)
- Performance of different Varieties of Mustard under Alkali Condition (Kanpur)
- Screening of Crop Varieties for Salt Tolerance (Bapatla)
- Tolerance of Cotton Varieties to Saline Water Irrigation under Drip System (Bikaner)
- Evaluation of different Crops for their Tolerance to Sodicity (Trichy)

Screening of Elite Varieties of Crops for Cultivation with Poor Quality Water - Hisar

The performances of different varieties of various field crops under saline water irrigation were evaluated. In year 2008-09, the tolerance of seven genotypes of cotton (NH-630, RCH-134 Bt, H-1117, H-1226, RAH-205, HAG-811 and RCH-134 nBt) and fourteen genotypes of wheat (P-3569, P-3622, WH-1068, WH-1070, WH-1082, WH-1083, WH-1084, WH-1085, WH-1086, WH-1090, WH-1091, WH-1094, WH-1021 and KRL-19) were tested under different saline water irrigation treatments i.e. canal water, EC_{iw} 2.5, 5.0 and 7.5 dS/m. The tolerance of six genotypes of oat (NGB-6370 x NGB-4462, NGB-6370 x HJ-8, NGB-6370 x OS-6, NGB-6370 x JHO 99-2, HJ-8 x NGB-7253 and NGB-4462 x HJ-8) were tested at an EC_{iw} of 12 dS/m.

In year 2009-10, the tolerance of seven genotypes of cotton (H-1117, H-1300, H-1236, H-1098-1, H-1226, HD-123 and HD-432), eight genotypes of wheat (WH-1103, WH-1104, WH-1105, WH-1106, WH-1107, WH-1108, Kharchia-65 and KRL-19) and eighteen genotypes of mustard (IVT-I: CSCN-09-1, CSCN-09-2, CSCN-09-3, CSCN-09-4, CSCN-09-5, CSCN-09-6, CSCN-09-7, CSCN-09-8, CSCN-09-9, CSCN-09-10, CSCN-09-11, CSCN-09-12, AVT-II: CSCN-09-13, CSCN-09-14, CSCN-09-15, CSCN-09-16, CSCN-09-17 and CSCN-09-18) were tested under different saline water irrigation treatments i.e. canal water, EC_{iw} 2.5, 5.0 and 7.5 dS/m. The tolerance of six genotypes of oat (JHO 99-2, NGB-6370, JHO-822, NGB-4462, NGB-4871 and JHO-851) and eleven genotypes of sorghum (IS651S, HC171, SSG-59-3, HC-260, HC-308, HJ-513, HC-136, IS3237, IS2389, SGL-87 and G-46) was tested under different saline water irrigation treatments i.e. canal water, EC_{iw} 4, 8 and 12 dS/m.

In cotton crop, increasing salinity led to a gradual decrease in cotton production (Table 165). At EC_{iw} of 7.5 dS/m, mean yield of all genotypes reduced by 39.2 per cent as compared to control. The mean yield of H-1117 was significantly higher than other genotypes followed by H-1226. The genotype NH-630 was the lowest yielder.

Table 165. Effect of saline waters (EC_{iw} dS/m) on seed yield of cotton genotypes

Genotypes	Seed cotton yield (g/m²)				
	Canal (0.5)	2.5	5.0	7.5	Mean
NH -630	122.8	133.2	112.0	75.0	110.75
RCH-134 Bt	296.6	360.7	299.3	211.1	291.92
H-1117	318.4	386.0	332.2	221.0	314.40
H-1226	357.4	394.6	286.9	202.3	310.30
RAH-205	191.4	132.6	116.3	104.2	136.12
HAG-811	259.2	186.3	135.2	132.6	178.32
RCH-134n Bt	267.5	265.6	192.8	156.0	220.47
Mean	259.0	265.6	210.7	157.5	
CD (5%)		Salinity : 17.22	Variety : 22.78	S x V : 45.57	

The individual boll weight (Table 166) was poorly correlated (R^2 = 0.304) whereas boll number/plant (Table 167) was strongly correlated (R^2 = 0.914) with cotton productivity. Indicating that extent of reduction in weight of an individual cotton boll was not a major contributory factor in reducing yields under saline conditions.

Production of monopods was reduced only under the highest level of salinity whereas sympod production was gradually reduced with increasing salinity (Table 168 and 169). Production of average monopods increased with the increase in salinity upto 5.0 dS/m and after that it was reduced and lower than the control (Table 168). Maximum monopods (7.0) were formed in RCH-134n Bt at an EC_{iw} of 5 dS/m.

Table 166. Effect of salinity of irrigation water on the weight of a cotton boll (g)

Genotypes	EC_{iw} (dS/m)				Mean
	Canal (0.5)	2.5	5.0	7.5	
NH -630	2.73	2.57	2.29	2.16	2.44
RCH-134 Bt	3.39	3.42	2.78	2.71	3.07
H-1117	2.87	3.04	2.70	2.38	2.75
H-1226	2.48	2.60	2.33	2.16	2.39
RAH-205	3.01	3.01	2.86	2.91	2.95
HAG-811	3.04	2.90	2.79	2.65	2.84
RCH-134 nBt	3.08	2.83	2.61	2.71	2.81
Mean	2.94	2.91	2.62	2.52	
% of control	100.00	98.97	89.11	85.71	

Table 167. Effect of salinity of water on bolls per plant of different cotton genotypes

Genotypes	EC_{iw} (dS/m)				Mean
	Canal (0.5)	2.5	5.0	7.5	
NH -630	8	8	6	5	6.75
RCH-134 Bt	10	14	14	11	12.25
H-1117	12	17	15	14	14.50
H-1226	14	18	12	11	13.75
RAH-205	9	7	9	7	8.00
HAG-811	10	8	8	7	8.25
RCH-134n Bt	12	12	11	9	11.00
Mean	10.71	12.0	10.71	9.14	
% of control		112.04	100.00	85.34	

Table 168. Effect of salinity on production of monopods in different cotton genotypes

Genotypes	EC_{iw} (dS/m)				Mean
	Canal (0.5)	2.5	5.0	7.5	
NH -630	3.6	5.6	3.0	3.6	3.95
RCH-134 Bt	2.3	3.6	3.6	5.6	3.77
H-1117	7.0	5.0	4.3	3.3	4.90
H-1226	4.0	3.3	3.3	2.6	3.3
RAH-205	5.3	5.3	7.3	3.0	5.22
HAG-811	4.0	3.6	7.6	3.6	4.70
RCH-134n Bt	4.3	6.6	7.0	4.3	5.55
Mean	4.35	4.71	5.15	3.71	
% of control	100.00	108.27	118.39	85.28	

Production of average sympods decreased with the increase in salinity (Table 169). The maximum average sympods was 24.42 at control and minimum sympods was 19.28 at an EC_{iw} of 7.5 dS/m. NH-630 formed minimum number of sympods (14) at an EC of 7.5 dS/m, whereas, RAH-205 formed maximum number of sympods (30) at control. Amongst the various physiological parameters studied, ELWL%, an indication of rates of transpiration, (Table 170) showed a poor relationship with EC ($R^2 = 0.434$).

Table 169. Effect of salinity on production of sympods in different cotton genotypes

Genotypes	EC_{iw} (dS/m)				Mean
	Canal (0.5)	2.5	5.0	7.5	
NH -630	25	18	28	14	21.25
RCH-134 Bt	19	25	16	18	19.50
H-1117	29	20	20	23	23.00
H-1226	27	25	21	15	22.00
RAH-205	30	29	25	25	27.25
HAG-811	23	18	18	21	20.50
RCH-134n Bt	18	20	24	19	20.25
Mean	24.42	22.14	21.71	19.28	
% of control	100.0	90.7	88.9	78.9	

Table 170. Effect of salinity on ELWL % shown by different cotton genotypes

Genotypes	EC_{iw} (dS/m)				Mean
	Canal (0.5)	2.5	5.0	7.5	
NH -630	17.0	15.7	23.3	21.6	19.4
RCH-134 Bt	16.3	20.7	20.1	19.8	19.2
H-1117	29.2	27.7	27.0	21.3	26.3
H-1226	23.1	25.3	26.5	25.9	25.2
RAH-205	21.4	20.6	18.0	17.5	19.4
HAG-811	18.3	21.1	26.4	22.8	22.2
RCH-134n Bt	21.4	19.3	19.8	17.9	19.6
Mean	20.96	21.48	23.01	20.97	

Effect of salinity on assimilation of CO_2 µmol/m²/s shown by first fully expanded leaf from the top of cotton genotypes is given in Table 171. Photosynthetic efficiency was having a good correlation value of 0.674 with cotton yield. Spad readings (Table 172), an indication of the chlorophyll content in the top fully leaves did not show any consistent pattern, there was a poor correlation with photosynthetic efficiency ($R^2 = 0.378$). Stomatal conductance (Table 173) was also not correlated with Photosynthetic efficiency (Table 174) whereas it was having a good correlation with transpiration rates ($R^2 = 0.547$).

Table 171. Effect of salinity on assimilation of CO_2 shown by first fully expanded leaf of cotton genotypes

Genotypes	Assimilation of CO_2 (µmol/m²/s)				
	Canal (0.5 dS/m)	2.5 dS/m	5.0 dS/m	7.5 dS/m	Mean
NH -630	18.70	16.98	12.51	11.72	14.98
RCH-134 Bt	18.43	18.80	18.19	13.96	17.34
H-1117	20.55	25.45	19.15	17.99	20.78
H-1226	17.17	20.07	15.83	12.43	16.37
RAH-205	15.83	15.10	14.61	12.87	14.60
HAG-811	20.56	22.72	16.75	13.26	18.32
RCH-134 nBt	17.41	21.50	18.46	16.56	18.48
Mean	18.38	20.09	16.50	14.11	

Table 172. Effect of salinity on chlorophyll (spad readings) shown by first fully expanded leaf of cotton genotypes

Genotypes	Chlorophyll (spad readings) per cent				
	Canal (0.5 dS/m)	2.5 dS/m	5.0 dS/m	7.5 dS/m	Mean
NH -630	14.2	18.2	14.0	14.5	15.22
RCH-134 Bt	20.1	21.6	15.2	15.8	18.17
H-1117	13.7	25.2	24.6	20.9	21.10
H-1226	16.2	23.6	19.9	21.6	20.32
RAH-205	15.3	16.0	13.7	13.2	14.55
HAG-811	13.8	15.2	15.1	14.5	14.65
RCH-134n Bt	17.6	15.8	17.3	15.2	16.47
Mean	15.84	19.37	17.11	16.53	

Table 173. Effect of salinity on stomatal conductance of the first fully expanded leaf from the top of cotton genotypes

Genotypes	Stomatal conductance (mmol CO_2 /m^2 /s)				
	Canal (0.5 dS/m)	2.5 dS/m	5.0 dS/m	7.5 dS/m	Mean
NH -630	0.83	0.14	0.49	0.32	0.44
RCH-134 Bt	0.57	2.47	0.55	0.26	0.96
H-1117	0.65	0.40	0.19	0.36	0.40
H-1226	0.34	0.06	0.07	0.06	0.13
RAH-205	0.50	0.13	0.16	0.24	0.26
HAG-811	0.12	0.67	0.25	0.11	0.29
RCH-134 nBt	0.36	0.42	0.10	0.42	0.32
Mean	0.48	0.61	0.26	0.25	

Table 174. Effect of salinity on transpiration of H_2O shown by first fully expanded leaf of cotton genotypes

Genotypes	Transpiration of H_2O (µmol/m^2/s)				
	Canal (0.5 dS/m)	2.5 dS/m	5.0 dS/m	7.5 dS/m	Mean
NH -630	3.57	3.75	5.92	4.2	4.36
RCH-134 Bt	7.84	9.64	6.42	5.94	7.46
H-1117	8.99	7.10	5.48	7.74	7.33
H-1226	7.37	2.89	3.11	2.91	4.07
RAH-205	6.33	4.77	5.32	6.62	5.76
HAG-811	8.04	8.77	6.18	4.16	6.78
RCH-134 nBt	4.26	7.57	3.66	7.87	5.84
Mean	6.63	6.35	5.15	5.63	

During 2009-10, in cotton crop it was observed that increasing salinity generally led to a gradual decrease in cotton production (Table 175). At EC_{iw} of 7.5 dS/m, yield reduced by 58.5 per cent as compared to control treatment. The mean yield of H-1236 was 228.8 g/m^2 which was significantly higher than other genotypes followed by H-1117. Desi cotton varieties were highly sensitive, HD-123 being the most sensitive followed by HD-432. The mean seed cotton yield of genotypes HD-123 and HD-432 were 40.3 and 77.3 g/m^2, respectively.

Boll weight decreased with increase in the level of salinity in four of the seven genotypes whereas in other genotypes, there is an increase in boll weight upto 2.5 dS/m but after that there is decrease in these genotypes also.

Table 175. Effect of saline waters on seed cotton yield of cotton genotypes

Genotypes	Seed cotton yield (g/m²)				
	Canal (0.5 dS/m)	2.5 dS/m	5.0 dS/m	7.5 dS/m	Mean
H-1117	165.0	241.7	149.7	105.3	165.4
H-1300	248.0	209.0	109.0	72.0	159.5
H-1236	307.0	229.0	208.3	171.0	228.8
H-1098-1	143.7	201.0	133.7	132.0	152.6
H-1226	172.0	146.0	94.7	74.3	121.8
HD-123	131.0	20.7	9.3	0.0	40.3
HD-432	169.0	86.3	54.0	0.0	77.3
Mean	190.8	162.0	108.4	79.2	
CD (5%)		Salinity : 5.99	Variety : 7.92	S x V : 15.85	

Number of open bolls decreased under saline conditions in all the genotypes except in H-1226 with a salinity level of 2.5 dS/m. The individual boll weight was strongly correlated (R^2=0.873) whereas boll number/plant also showed a good correlation (R^2=0.834) with cotton productivity indicating that both contributed towards reducing yields under saline conditions.Number of monopod of cotton genotype decreased under saline conditions in all the genotypes except in H-1236 with a salinity level of 2.5 dS/m. Mean monopod number (3.95) was the highest in H-1117 genotype followed by H-1300, having its value 3.13, whereas, in HD-123 was the lowest (1.00).

Effect of salinity on number of sympods was also studied (Fig. 48). Number of sympods of cotton genotype increased upto 2.5 dS/m in all the genotypes except in H-1098-1 and H-1226 and after 2.5 dS/m, the decrease in number of sympods was observed in all genotypes. Mean of sympod number varied from 15 to 29 in different genotypes from H-1098-1 to HD-432, respectively. Maximum numbers of sympod (41) was observed in HD-432 at 2.5 dS/m.

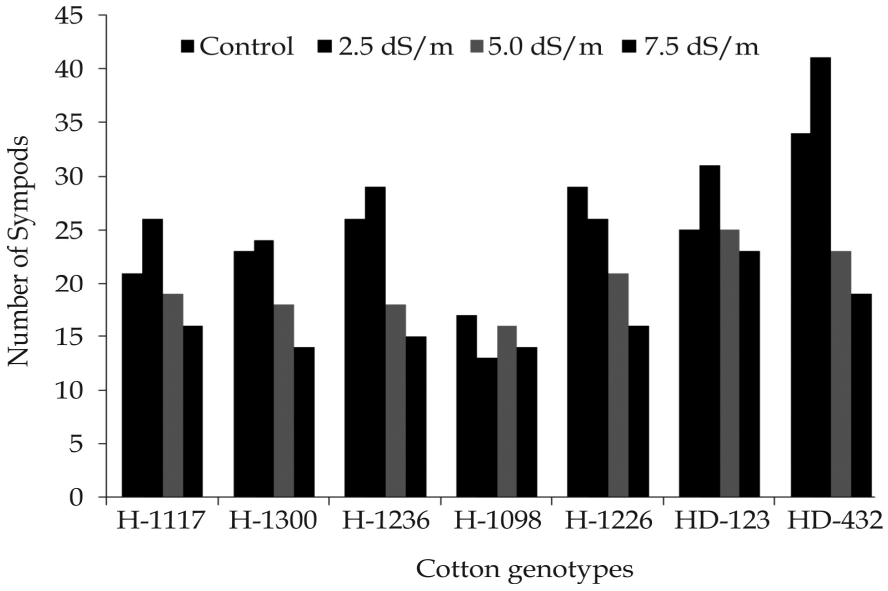


Fig. 48. Effect of salinity on sympod number in cotton genotypes

Various physiological parameters (ELWL%, transpiration rate, photosynthesis rate, chlorophyll status) and nutrient contents were also studied. For ELWL%, sampling was done thrice during the experiment. During first sampling, average ELWL% varied from 10.12 to 15.48 with the lowest value in H-1117 genotype and the highest value in HD-123. During second sampling, average ELWL%

varied from 15.46 to 24.81 with the lowest value in H-1300 genotype and the highest value in HD-123. During third sampling, average ELWL% varied from 18.49 to 39.35 with the lowest value in H-1098-1 genotype and the highest value in HD-123. In these three samplings, the lowest value shifted among different genotypes whereas, the highest value remained only in HD-123 genotype.

Salinity affected adversely the transpiration rate (H_2O mmol/m^2/s). With the increase in EC level, transpiration rate decreased except in H-1117 genotype upto 2.5 dS/m. Transpiration rate is highly affected in HD-123 genotype as compared to other genotypes (Fig. 49). Average transpiration rate varied from 2.68 to 3.94 with the lowest value in H-1117 genotype and the highest value in HD-123.

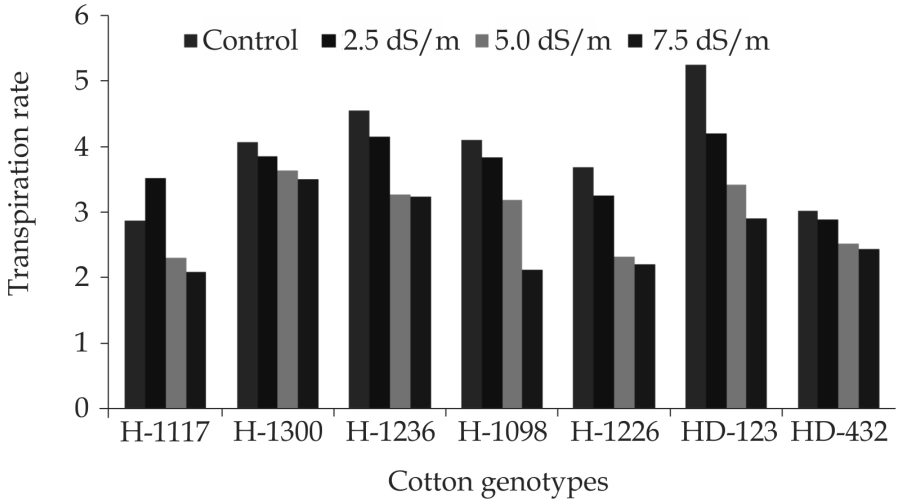


Fig. 49. Effect of salinity on Transpiration rate (H_2O mmol/m^2/s)

Rate of photosynthesis were generally reduced with the increasing salinity except at a level of 2.5 dS/m. The increase was observed even in H-1117 and H-1098-1 genotypes but no change was observed in H-1300. Photosynthesis rate is highly affected in HD-432 genotype as compared to other genotypes (Fig. 50). Average photosynthesis rate varied from 9.53 to 12.88 with the lowest value in HD-432 genotype and the highest value in H-1300. Desi variety HD-123 showed least reduction in the rates of photosynthesis. Photosynthetic efficiency was observed to have a good correlation ($r^2 = 0.707$) with cotton yield. Assimilation rate (µmol CO_2 /m^2 /s) has almost shown similar trend as photosynthesis rate.

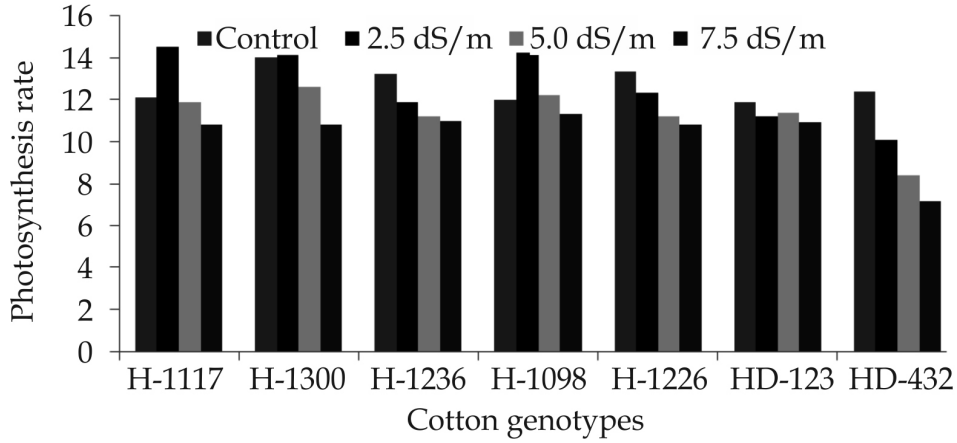


Fig. 50. Effect of salinity on photosynthesis rate (µmol CO_2 /m^2 /s)

Stomatal conductance decreased with the increase in salinity in all genotypes (Table 176) except genotypes H-1300 in which an increase was observed upto 2.5 dS/m. HD-123 showed a maximum decrease in stomatal conductance whereas H-1300 showed least reduction by increase in salinity.

Table 176. Effect of salinity on stomatal conductance

Genotypes	Stomatal conductance (mmol CO_2 /m^2 /s)				
	Canal (0.5 dS/m)	2.5 dS/m	5.0 dS/m	7.5 dS/m	Mean
H-1117	0.19	0.20	0.11	0.09	0.15
H-1300	0.18	0.24	0.18	0.12	0.18
H-1236	0.27	0.22	0.15	0.15	0.20
H-1098-1	0.18	0.17	0.13	0.09	0.14
H-1226	0.23	0.15	0.12	0.08	0.15
HD-123	0.29	0.20	0.11	0.10	0.18
HD-432	0.10	0.08	0.07	0.05	0.08
Mean	0.21	0.18	0.12	0.10	

Nitrogen content of the leaves of cotton plants increased at lower levels of salinity but decreased at the highest level 7.5 dS/m (Table 177). Phosphorus (Table 178) and potassium (Table 179) content of the leaves generally decreased with increasing levels of salinity whereas sodium (Table 180) content generally increased with the increasing levels of the salinity.

Table 177. Effect of salinity on nitrogen content (%) of the leaves of cotton

Genotypes	Nitrogen percentage				
	Canal (0.5 dS/m)	2.5 dS/m	5.0 dS/m	7.5 dS/m	Mean
H-1117	2.24	2.22	2.19	2.05	2.18
H-1300	2.25	2.62	2.19	1.75	2.20
H-1236	2.15	2.12	2.16	1.99	2.11
H-1098-1	2.07	2.55	1.9	1.89	2.10
H-1226	2.19	2.22	2.1	2.13	2.16
HD-123	2.47	2.37	2.32	2.22	2.35
HD-432	2.15	2.85	2.19	1.95	2.29
Mean	2.22	2.42	2.15	2.00	

Table 178. Effect of salinity on phosphorus content (%) of the leaves of cotton

Genotypes	Phosphorus percentage				
	Canal (0.5 dS/m)	2.5 dS/m	5.0 dS/m	7.5 dS/m	Mean
H-1117	0.279	0.188	0.176	0.159	0.201
H-1300	0.209	0.124	0.092	0.075	0.125
H-1236	0.163	0.131	0.119	0.057	0.118
H-1098-1	0.163	0.161	0.112	0.087	0.131
H-1226	0.187	0.146	0.12	0.075	0.132
HD-123	0.143	0.097	0.045	0.015	0.075
HD-432	0.182	0.143	0.136	0.112	0.143
Mean	0.189	0.141	0.114	0.083	

Mean EC (1:2) in the soil profile upto 45 cm varied from 0.40 to 2.09 dS/m from control to 7.5 dS/m plots (Fig. 51) at the time of sowing. EC in the soil profile under 7.5 dS/m EC plot remained highest throught out the soil profile as compared to other treatments.

Table 179. Effect of salinity on potassium content (%) of the leaves of cotton

Genotypes	Potassium percentage				
	Canal (0.5 dS/m)	2.5 dS/m	5.0 dS/m	7.5 dS/m	Mean
H-1117	1.81	1.74	1.63	1.58	1.69
H-1300	2.02	1.86	1.91	1.58	1.84
H-1236	1.98	1.82	1.74	1.75	1.82
H-1098-1	1.83	1.75	1.69	1.71	1.75
H-1226	1.79	1.71	1.65	1.64	1.70
HD-123	1.74	1.69	1.67	1.50	1.65
HD-432	1.81	1.75	1.71	1.65	1.73
Mean	1.85	1.76	1.71	1.63	

Table 180. Effect of salinity on sodium content (%) of the leaves of cotton

Genotypes	Sodium percentage				
	Canal (0.5 dS/m)	2.5 dS/m	5.0 dS/m	7.5 dS/m	Mean
H-1117	1.51	1.51	1.71	1.92	1.66
H-1300	1.50	1.54	1.7	1.77	1.63
H-1236	1.32	1.60	1.74	1.76	1.61
H-1098-1	1.51	1.51	1.70	1.74	1.62
H-1226	1.50	1.63	1.64	1.60	1.59
HD-123	1.30	1.33	1.32	1.46	1.35
HD-432	1.23	1.4	1.48	1.79	1.48
Mean	1.41	1.50	1.61	1.72	

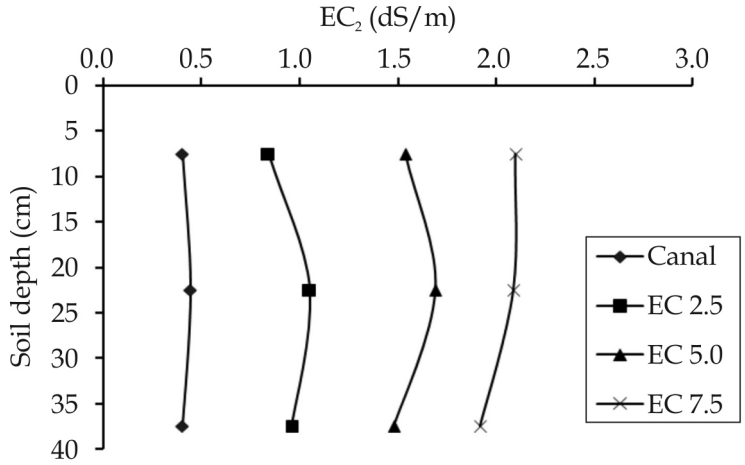


Fig. 51. Electrical conductivity of the soil under different treatments at the sowing of cotton

In wheat crop the yield of different varieties of wheat decreased with an increase in EC of the irrigation water (Table 181). The genotypes WH-1083 and WH-1085 gave the maximum yield (375 g/m^2) followed by WH-1084 (350 g/m^2) at EC_{iw} of 7.5 dS/m. However, the genotypes KRL-19, P-3569 (200 g/m^2) and P-3622 (225 g/m^2) yielded comparatively much less than other genotypes. At EC_{iw} of 7.5 dS/m, mean yield of all genotypes reduced by 35.1 per cent as compared to control treatment. The mean yield of WH-1084 was significantly higher than other genotypes followed by WH-1085. The genotype KRL-19 was the lowest yielder.

Table 181. Grain yield (g/m^2) of wheat varieties as affected by different salinity waters

Varieties	Wheat grain yield (g/m²)				
	Canal (0.5 dS/m)	2.5 dS/m	5.0 dS/m	7.5 dS/m	Mean
P-3569	425	300	250	200	293.75
P-3622	375	325	275	225	300.00
WH-1068	500	500	350	275	406.25
WH-1070	525	425	375	300	406.25
WH-1082	400	375	300	275	337.50
WH-1083	450	425	400	375	412.50
WH-1084	525	475	450	350	450.00
WH-1085	500	475	425	375	443.75
WH-1086	350	350	300	275	318.75
WH-1090	500	450	375	300	406.25
WH-1091	375	350	325	250	325.00
WH-1094	425	400	325	275	356.25
WH-1021	475	450	375	300	400.00
KRL-19	300	225	225	200	237.50
Mean	437.50	394.64	339.29	283.93	
CD (5%)	Variety (V) : 58.90; Salinity (S) : 31.49; V x S : NS				

In oat (*Avena sativa L.*), Out of 12 genotypes identified as salinity tolerant and sensitive during 2007-08, a total no. of six (NGB-6370 x NGB-4462, NGB-6370 x HJ-8, NGB-6370 x OS-6, NGB-6370 x JHO 99-2, HJ-8 x NGB-7253 and NGB-4462 x HJ-8) single crosses were prepared for F1 generation during the year 2008-09 using half dialed mating design. It was observed that based upon the various morpho-physiological traits, the plant type of NGB-6370 x JHO 99-2 and HJ-8 x NGB-7253 showed better salinity tolerance than others (Table 182). The plant type of HJ-8 x NGB-7253 showed its earliness by 20 days for its maturity.

Table 182. Dry matter yield of F1 generation at EC_{iw} 12 dS/m

Cross	Yield (g/plant)
NGB-6370 x NGB-4462	6.00
NGB-6370 x HJ-8	4.30
NGB-6370 x OS-6	4.96
NGB-6370 x JHO 99-2	9.04
HJ-8 x NGB-7253	9.44
NGB-4462 x HJ-8	4.74

At a salinity level of l2 dS/m, the maximum plant height was observed in plant progeny of NGB-6370 x HJ-8 (88.0 cm) followed by NGB-6370 x OS-6 (81.0 cm) and HJ-8 x NGB-7253 (75.3 cm), whereas minimum plant height was recorded in NGB-6370 x NGB 4462 (62.0 cm) (Table 37). The maximum fresh weight per plant was recorded in plant progeny of HJ-S x NGB-7253 (l30.0 g) followed by NGB-6370 x JHO 99-2 (100.0 g) and NGB-6370 x NGB-4462 (83.33 g). The minimum fresh weight was observed in the cross NGB-4462 x HJ-8 (63.33 g). A similar trend was observed for dry weight and leaf area per plant in various plant progeny of F_1 generation (Table 183).

Table 183. Effect of salinity on some growth parameters in F1 generation of six crosses of oat

F1 Crosses	Plant height (cm)	Fresh weight per plant (g)	Dry weight per plant (g)	Leaf area (cm^2)
NGB 6370 x NGB 4462	62.0 ± 4.0	83.33 ± 4.41	6.003 ± 0.107	2,170.9 ± 140.8
NGB 6370 x HJ-8	88.0 ± 1.1	66.66 ± 1.66	4.297 ± 0.108	1,276.3 ± 49.6
NGB 6370 x OS-6	81.0 ± 1.1	70.00 ± 2.88	4.960 ± 0.214	1,606.0 ± 44.7
NGB 6370 x JHO 99-2	64.3 ± 2.2	100.00 ± 13.92	9.047 ± 0.152	3,182.7 ± 101.9
HJ-8 x NGB 7253	75.3 ± 4.0	130.00 ± 8.66	10.103 ± 0.631	3,726.9 ± 56.6
NGB 4462 x HJ-8	63.6 ± 4.8	63.33 ± 6.01	4.745 ± 0.178	2,201.2 ± 39.2

Effect of salinity on some physiological traits

a) Water relations

Relative water content: The relative water content (RWC) of various plant progenies of F_1 generation did not show much variation in their values (Table 184).

Osmotic potential (Ψs): The osmotic potential (Ψs) of leaf was more (-ve) in NGB-6370 x HJ-8 (-2.22 MPa) followed by HJ-8 x NGB-7253 (-2.10 MPa) and NGB 6370 x JHO 99-2 (-1.96 MPa). The less '-ve' value (-1.76 MPa) was observed in the cross NGB-4462 x HJ-8 (Table 184).

b) Membrane injury

Relative stress injury (RSI): The data present in Table 184 revealed that maximum relative stress injury (%) of leaves was in the cross NGB-6370 x OS-6 (17.86 per cent) followed by NGB-6370 x NGB-4462 (14.83 per cent) and NGB-6370 x HJ-8 (14.31 per cent). The minimum RSI % i.e. 13.37 per cent was in the cross NGB-6370 x JHO 99-2 and HJ-8 x NGB-7253.

MDA (Malondialdehyde) content: The highest amount of MDA content was estimated in the cross NGB-6370 x HJ-8 (241.61 per cent) followed NGB-6370 x OS-6 (237.15 per cent) while minimum was found in HJ-8 x NGB-7253 (134.39 per cent) (Table 184).

Table 184. Effect of salinity on physiological traits in F1 generation of six crosses of oat at

F1 Crosses	RSI (%)	MDA (µg/g dw)	Total chl. content (µg/g dw)	Ψs (-MPa)	RWC (%)
NGB-6370 x NGB-4462	14.83 ± 0.47	201.42 ± 7.11	23.95 ± 5.72	1.79 ± 0.027	90.92 ± 0.22
NGB-6370 x HJ-8	13.49 ± 0.63	241.61 ± 5.46	18.20 ± 4.22	2.22 ± 0.014	92.79 ±0.56
NGB-6370 x OS-6	17.86 ± 1.18	237.15 ± 2.40	25.09 ± 5.69	1.92 ± 0.021	92.97 ± 0.35
NGB-6370 x JHO 99-2	13.37 ± 1.51	155.51 ± 12.8	28.99 ± 4.48	1.96 ± 0.020	92.20 ± 2.94
HJ-8 x NGB-7253	13.37 ± 0.41	134.39 ± 5.95	25.92 ± 4.18	2.10 ± 0.009	93.10 ± 1.30
NGB-4462 x HJ-8	14.31 ± 0.38	199.01 ± 8.20	23.04 ± 4.11	1.76 ± 0.010	90.74 ± 0.84

Vegetative stage

c) Total chlorophyll content

The plant progeny of NGB-6370 x JHO 99-2 showed maximum total chlorophyll content (28.99 µg/g dw) followed by HJ-8 x NGB-7253 (25.92 µg/g dw) and NGB-6370 x OS-6 (25.09 µg/g dw). The minimum chlorophyll content was observed in NGB-6370 x HJ-8 (18.20 µg/g dw) (Table 184).

d) Chlorophyll fluorescence studies

The quantification of the chlorophyll fluorescence transients (OUP Test) revealed large plant progeny differences of F_1 generation in response of PS II to the salinity level of 12 dS/m. The maximum activity of PS II or (maximum quantum yield of PS II) i.e. (1-Fo/Fm) was noticed in HJ-8 x NGB-7253 (0.413) followed by NGB-6370 x JHO 99-2 (0.346) and the lowest in NGB-6370 x HJ-8 (0.143) (Table 185). The tolerant plant progenies always maintained higher values of this parameter as compared to the susceptible plant progenies. The tolerant plant progenies to some extent prevented the damage caused by salinity.

Table 185. Effect of salinity on photochemical activity PS II (maximum quantum yield of PS II) in F1 generation of six crosses of oat at vegetative stage

F1 Crosses	Fo	Fm	Fo/Fm	l-(Fo/Fm)
NGB-6370 x NGB 4462	220 ± 1.2	332 ± 2.3	0.662	0.337
NGB-6370 x HJ-8	187 ± 4.8	218 ± 5.5	0.857	0.143
NGB-6370 x OS-6	212 ± 8.8	259 ± 4.6	0.818	0.182
NGB-6370 x JHO 99-2	216 ± 12.7	330 ± 55.1	0.654	0.346
HJ-8 x NGB-7253	214 ± 7.8	264 ± 16.0	0.587	0.413
NGB-4462 x HJ-8	181 ± 2.2	224 ± 14.9	0.809	0.190

In wheat crop during 2009-10, the yield of different varieties of wheat when irrigated with different qualities of water is presented in Table 186. The data showed that the yield of different varieties of wheat decreased with an increase in EC of the irrigation water. Wheat genotype WH-1105 performed best at the highest saline water irrigation (7.5 dS/m) and gave 47 per cent higher yield when compared with KRL-19 (check). It is followed by WH-1107 which gave 16 per cent higher yield than KRL-19 whereas the performance of WH-1103 was the poorest and gave 27 per cent lower yield when compared with KRL-19 (check). Genotype WH-1105 is more tolerant to salinity due to less reduction in the photosynthetic rate at higher salinity. Percent reduction in the yield of different varieties of wheat was worked out under different salinity by comparing with non-saline (control) treatment. The highest percent reduction (33.91) in the yield was observed in WH-1103 under 7.5 dS/m when compared to control. In WH-1106, WH-1107, WH-1108, increase in yield was observed when irrigated with 2.5 dS/m EC water as compare to canal and maximum value of this increase was 5.45 percent in WH-1107 variety.

Table 186. Grain yield (g/m^2) of wheat varieties as affected by different salinity waters

Varieties	Grain yield of wheat (g/m^2)				Mean
	Canal (0.5 dS/m)	2.5 dS/m	5.0 dS/m	7.5 dS/m	
WH-1103	254.70	193.55	243.59	168.33	215.04
WH-1104	287.30	283.88	247.46	260.39	269.76
WH-1105	370.96	298.58	314.04	339.11	330.67
WH-1106	291.11	301.52	282.69	242.84	279.54
WH-1107	352.22	371.42	348.28	267.98	334.98
WH-1108	286.74	292.96	257.62	223.82	265.29
Kharchia-65	366.09	289.74	275.22	323.09	313.53
KRL-19	252.66	246.53	242.76	230.68	243.16
Mean	307.72	284.77	276.46	257.03	
CD (5%)	Variety (V) : 42.98; Salinity (S) : 30.39; V x S : NS				

Physiological observations on photosynthetic rate, transpiration rate, stomatal conductance, intercellular CO_2 concentration, and chlorophyll fluorescence were recorded under different treatments. There was significant difference in photosynthetic and transpiration rate at different level of salinity. Value of stomatal conductance also decreased with increase in the salinity of irrigation water but this change was non-significant. Intercellular CO_2 conc. (ppm) increased with the increase in salinity in KRL-19, WH-1107, and WH-1106, whereas, it decreased in WH-1104, WH-1103, Kh-6, WH-1105 and WH-1108 (Table 187). The maximum value (333) of intercellular CO_2 conc. was observed in WH-1108 under canal water irrigation and the lowest value (192) was found in WH-1105 when irrigated with 7.5 dS/m. Chlorophyll fluorescence was least affected by salinity. Its average value for different varieties varied from 0.725 (WH-1103) to 0.778 (WH-1107).

Table 187. Effect of salinity on intercellular CO_2 concentration (ppm) of wheat

Varieties	Intercellular CO_2 concentration (ppm) of wheat				Mean
	Canal (0.5 dS/m)	2.5 dS/m	5.0 dS/m	7.5 dS/m	
KRL-19	255	200	221	283	240
WH-1104	212	239	241	201	223
WH-1103	230	291	223	198	236
Kh-65	288	282	278	192	260
WH-1107	229	259	315	278	270
WH-1105	229	250	268	212	240
WH-1108	333	261	248	263	276
WH-1106	278	274	208	321	270
Mean	257	257	250	244	

During 2009-2010, in oat crop, samplings for various morpho-physiological parameters (plant height, fresh weight, relative stress injury (RSI%) and chlorophyll fluorescence values,) were done at vegetative stage i.e. 30-35 days after sowing (DAS) and at 50 per cent flowering stage of each of the genotype, respectively. With an increase in the EC of irrigation water from 4 dS/m to 12 dS/m, there was a significant reduction in morphological characters in all the oat genotypes. At vegetative stages, the plant height decreased by 16.77 and 37.99 per cent at EC 4 dS/m and 12 dS/m respectively as compared to control. Similarly, fresh weight/plant was also decreased from 24.27 to 55.50 per cent. Similar reductions were also reported at flowering stage with some variations.

The relative stress injury (RSI) of leaf at vegetative stage significantly increased from 89.08 to 91.78 per cent at 4 dS/m and 12 dS/m salinity levels as compared to control (86.99 per cent) (Table 188). The chlorophyll fluorescence values decreased from 0.45 to 0.36 as the EC_{iw} increased from 4 dS/m to 12 dS/m (Table 189).

Table 188. Effect of salinity on relative stress injury (%) at vegetative stage

Genotypes	EC_{iw} (dS/m)				Mean
	Canal	4	8	12	
JHO 99-2	82.4	82.9	85.4	87.4	84.5
NGB 6370	85.4	90.0	91.5	92.4	89.8
JHO 822	85.9	91.1	91.3	91.9	90.0
NGB 4462	91.1	91.4	93.1	94.5	92.6
NGB 4871	89.4	92.1	93.1	94.0	92.2
JHO 851	87.7	89.0	92.2	93.5	90.6
Mean	87.0	89.4	91.1	92.3	
CD (5%)	Variety (V): 0.7; Salinity (S): 0.6; V x S: 1.3				

Table 189. Effect of salinity on chlorophyll fluorescence values at vegetative stage

Genotypes	EC_{iw} (dS/m)				Mean
	Canal	4	8	12	
JHO-99-2	0.55	0.63	0.52	0.48	0.54
NGB-6370	0.46	0.62	0.44	0.44	0.49
JHO-822	0.45	0.50	0.40	0.40	0.44
NGB-4462	0.39	0.39	0.39	0.32	0.37
NGB-4871	0.43	0.39	0.40	0.30	0.38
JHO-851	0.39	0.32	0.31	0.24	0.32
Mean	0.45	0.47	0.41	0.36	
CD (5%)	Variety (V): 0.02; Salinity (S): 0.01; V x S: 0.04				

In sorghum crop during 2009-10, eleven genotypes were evaluated for fodder yield, component traits and quality under different salinity conditions. There was significant decrease in the fodder yield and its components with the increased level of salinity (Table 190). The genotype HC-136 was most tolerant to salinity followed by HC-171, HC-308 and SSG-59-3, whereas, the genotypes SGL-87 and IS-2389 were most sensitive to salinity.

Table 190. Effect of salinity on fodder yield (kg/m²) of sorghum genotypes

Genotypes	EC_{iw} (dS/m)				Mean
	Canal	4	8	12	
IS-651-S	3.71	3.50	3.34	2.81	3.34
HC-171	3.44	3.38	3.21	2.91	3.24
SSG-59-3	2.88	2.76	2.52	2.28	2.61
HC-260	2.40	2.28	2.02	1.88	2.15
HC-308	3.69	3.42	3.25	3.00	3.34
HJ-513	3.59	3.36	3.15	2.88	3.25
HC-136	3.44	3.27	3.20	2.91	3.21
IS-3237	3.12	2.99	2.43	2.32	2.72
IS-2389	3.33	2.60	2.53	2.34	2.70
SGL-87	3.40	3.22	2.58	1.74	2.74
G-46	2.98	2.71	2.25	1.95	2.47
Mean	3.27	3.04	2.77	2.46	

Screening of Mustard Cultivars for Saline Irrigation

Agra

An experiment was carried out on screening of mustard cultivars supplied by NRC on Rapeseed and Mustard, Bharatpur during 2008-2010. The crop was irrigated with saline water of EC_{iw} 12 dS/m.

During 2008-09, 21 cultivars of rapeseed mustard (AVT- 1 -16 and AVT- 11-5) were tested (Table 191). The data of mustard cultivars in AVT-1 and AVT-11 revealed that the grain yield varied from 1.03 to 2.35 t/ha. The highest yield was recorded with CSCN-08-16 (2.35 t/ha) followed by CSCN-08-15 (1.79 t/ha). In AVT-11, highest yield was recorded in CSCN-08-18 (1.20 t/ha) and lowest with CSCN-08-20 (0.98 t/ha). During 2009-10 total 18 cultivars (AVT-1-6 and IVT-12) were tested. The EC_{iw} was 12 dS/m. The highest yield was recorded in CSCN-09-14 (1.70 t/ha) and lowest in CSCN-09-16 (1.47 t/ha). In IVT highest grain yield was recorded in CSCN-09-12 (2.46 t/ha) and lowest in CSCN 09-9 (1.39 t/ha). In rest of the cultivars the yield potential was 1.42-2.06 t/ha. The average soil salinity was 4.0 dS/m at sowing and 11.0 dS/m at harvest during 2008-09. During 2009-10 the salinity was 3.7 dS/m which increased to 11.6 dS/m at harvest in surface layer (0-30cm).

Table 191. Effect of saline water irrigation on yield (t/ha) of mustard

2008-09		2009-10	
Genotypes	Seed yield	Genotypes	Seed yield
AVT-I		**AVT-I**	
CSCN-08-1	1.58	CSCN-09-13	1.64
CSCN-08-2	1.41	CSCN-09-14	1.70
CSCN-08-3	1.41	CSCN-09-15	1.64
CSCN-08-4	1.20	CSCN-09-16	1.47
CSCN-08-5	1.24	CSCN-09-17	1.65
CSCN-08-6	1.49	CSCN-09-18	1.67
CSCN-08-7	1.07	**IVT**	
CSCN-08-8	1.37	CSCN-089-01	2.06
CSCN-08-9	1.45	CSCN-09-02	1.70
CSCN-08-10	1.03	CSCN-09-03	1.78
CSCN-08-11	1.15	CSCN-09-04	1.69
CSCN-08-12	1.15	CSCN-09-05	1.42
CSCN-08-13	1.37	CSCN-09-06	1.89
CSCN-08-14	1.71	CSCN-09-07	1.53
CSCN-08-15	1.79	CSCN-09-08	1.92
CSCN-08-16	2.35	CSCN-09-09	1.39
AVT-II		CSCN-09-10	1.82
CSCN-08-17	1.14	CSCN-09-11	1.99
CSCN-08-18	1.20	CSCN-09-12	2.46
CSCN-08-19	1.10		
CSCN-08-20	0.98		
CSCN-08-21	1.18		

Hisar

During 2009-2010, twelve varieties of mustard were tested under IVT trials, whereas, six varieties were tested under AVT2 trials. The data showed that the yield of different genotypes of mustard decreased with an increase in EC of the irrigation water (Fig 52, Table 192). Effect of salinity build up in the soil on the yield of different genotypes of mustard under IVT and AVT2 trials are shown in Fig. 52, respectively. Under IVT trial, the genotypes CSCN-09-1 gave the maximum yield (184 g/m^2) followed by CSCN-09-12 (169 g/m^2) at EC_{iw} of 7.5 dS/m. Under AVT2 trial, the genotypes CSCN-09-15 and CSCN-09-16 gave the maximum yield (218 g/m^2) followed by CSCN-09-18 (213 g/m^2) at EC_{iw} of 7.5 dS/m. Under IVT trials, the mean yield varied from 158 to 222 g/m^2 in genotype CSCN-09-11 and CSCN-09-1, respectively. Under AVT2 trials, the mean yield varied from 206 to 280 g/m^2 in genotype CSCN-09-17 and CSCN-09-13, respectively.

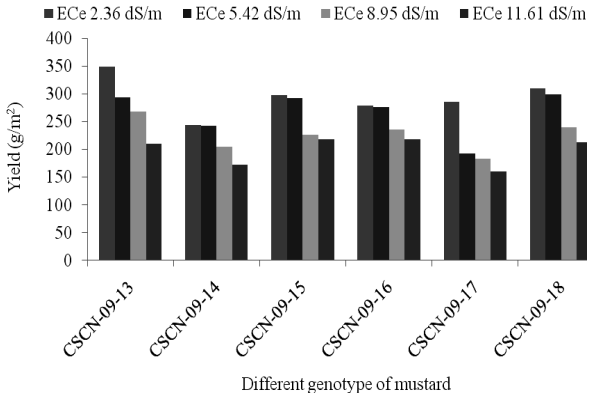


Fig. 52. Effect of salinity on the yield of different genotypes of mustard under AVT-II trial

Table 192. Seed yield (g/m²) of mustard varieties as affected by different salinity waters

Genotypes	Seed yield of mustard (g/m²)				Mean
	Canal (0.5 dS/m)	2.5 dS/m	5.0 dS/m	7.5 dS/m	
CSCN-09-1	275	237	191	184	222
CSCN-09-2	190	165	146	137	160
CSCN-09-3	207	187	177	148	180
CSCN-09-4	160	137	129	122	137
CSCN-09-5	198	166	148	131	161
CSCN-09-6	201	189	166	158	178
CSCN-09-7	234	209	178	155	194
CSCN-09-8	234	195	176	159	191
CSCN-09-9	201	181	169	145	174
CSCN-09-10	239	203	172	166	195
CSCN-09-11	191	164	144	134	158
CSCN-09-12	232	214	184	169	200
Mean	213	187	165	151	
CD (5%)	Variety (V) : 19.65; Salinity (S) : 11.34; V x S : NS				

By applying saline water of different EC i.e. canal, 2.5, 5.0 and 7.5 dS/m from last five year, the EC_e developed in the soil is shown in the Table 193. Mean EC_e in the soil profile upto 45 cm varied from 2.36 to 11.61 dS/m from control to 7.5 dS/m plots.

Table 193. EC_e build-up in the soil at sowing of mustard by saline water irrigation

Depth of soil (cm)	Canal (0.5 dS/m)	2.5 dS/m	5.0 dS/m	7.5 dS/m
0-15	2.28	4.79	8.78	11.97
15-30	2.51	5.99	9.63	11.91
30-45	2.28	5.47	8.44	10.94
Average	2.36	5.42	8.95	11.61

Bikaner

During 2008-09 sixteen genotypes of mustard under IVT and five genotypes under AVT were tested with irrigation water salinity of 8 dS/m for their salt tolerance. It was found that in IVT out of sixteen genotypes, significantly higher yield was produced by the genotype CSCN-13 followed by CSCN-5. The genotype CSCN-12 produced bolder seeds than other genotypes. Genotypes CSCN-6 produced taller plants followed by CSCN-4. The maximum number of siliqua/plant was highest in genotype CSCN-13 followed by CSCN-5 (Table 194).

In AVT, out of five genotypes CSCN-18 produced higher seed yield as compared to other genotypes. The genotype CSCN-17 produced bolder seeds than other genotypes.The genotype CSCN-19 produced taller plants while maximum number of siliqua/plant were in CSCN-18 followed by CSCN-20 (Table 194).

It is evident from the data presented in Table 195 that out of twelve genotypes under IVT significantly higher seed yield was produced by the genotype CSCN-10 followed by CSCN-4 and CSCN-8. The genotype CSCN-8 produced bolder seed than other genotypes. Days to 50% maturity ranged between 107 to 110 days. Genotypes CSCN-4 and CSCN-6 produced taller plants. The maximum number of siliqua /plant was produced by the genotype CSCN-4 and CSCN-10. Data on chemical characteristics after harvesting of crop indicate that EC_e of surface soil (0-15 cm) increased from 0.50 to 2.85 dS/m and pH_s increased from 8.19 to 8.43 due to irrigation with saline water (Table 196).

Table 194. Effect of saline water irrigation on yield and yield attributes of mustard (2008-09)

Variety code	Seed yield (t/ha)	Plant stand/m row length	Days to 50% maturity	1000-seed weight (g)	Plant height (cm)	Siliqua/ plant
			IVT			
CSCN- 1	0.56	5.1	108	4.42	123	160.7
CSCN- 2	0.67	5.1	107	4.02	129	162.7
CSCN- 3	0.52	5.2	109	3.69	138	192.0
CSCN- 4	0.62	5.1	109	4.67	142	197.7
CSCN- 5	0.82	5.5	107	4.57	129	214.7
CSCN- 6	0.49	5.2	109	3.56	144	187.0
CSCN- 7	0.60	5.1	107	5.07	121	170.0
CSCN- 8	0.49	5.0	108	4.64	134	142.7
CSCN-9	0.70	5.1	108	3.63	130	204.0
CSCN-10	0.78	5.3	109	4.47	125	211.0
CSCN- 11	0.43	5.1	110	4.02	128	160.0
CSCN- 12	0.48	5.3	110	5.16	134	162.0
CSCN- 13	0.93	5.1	108	4.68	132	247.7
CSCN- 14	0.59	5.4	109	4.33	138	166.7
CSCN- 15	0.56	5.1	107	4.20	137	194.0
CSCN- 16	0.60	5.0	108	4.08	127	202.0
S.Em ±	0.60	0.3	0.7	0.06	4.9	15.6
CD (5%)	0.17	NS	NS	0.16	14.2	45.1
			AVT			
CSCN-17	0.42	5.2	108	4.20	122	187.7
CSCN-18	0.73	5.3	108	3.90	137	286.7
CSCN-19	0.46	5.6	108	3.38	141	205.3
CSCN- 20	0.56	5.7	107	3.43	130	256.0
CSCN- 21	0.53	5.5	108	3.76	137	214.0
S.Em ±	0.05	0.3	0.4	0.06	2.6	17.5
CD (5%)	0.16	NS	NS	0.20	8.4	57.2

Twelve and six genotypes under IVT and AVT were tested during 2009-10 with saline water having EC_{iw} 9.0 dS/m

Out of six genotypes under AVT, genotype CSCN-15 produced higher seed yield as compared to other genotypes. Days to maturity ranged from 136 to 140. Data on chemical characteristics after harvesting of crop indicate that EC_e of surface soil (0-15 cm) increased from 0.49 to 2.87 dS/m and pH_s increased from 8.29 to 8.40 due to irrigation with saline water (Table 197).

Performance of different Varieties of Mustard under Alkali Condition - Kanpur

Twenty one and eighteen varieties of Indian mustard were sown during November 2008 and 2009 respectively at seed production farm Dalipnagar, Kanpur, to study the salt tolerance at ESP 41.5 and 42.0. Recommended doses of fertilizer i.e. NPK were applied @ 80:40:40 kg/ha. Half dose of nitrogen and full doses of phosphorus and potash were applied at the time of sowing and remaining dose of nitrogen was top dressed in two split at 25 days interval. Distance of row to row 30 cm and plant to plant 10 cm was maintained. Inter cultural operations; irrigations were given as and when required.

Table 195. Effect of saline water irrigation on yield attributes and yield of mustard (2009-10)

Variety code	Seed yield (t/ha)	Plant stand/m row length	Days to 50% maturity	1000-seed weight (g)	Plant height (cm)	Siliqua/ plant
			IVT			
CSCN- 1	1.06	5.2	108	4.03	123	191
CSCN- 2	1.26	5.1	107	4.85	129	205
CSCN- 3	1.03	5.2	109	4.12	138	192
CSCN- 4	1.34	5.4	109	4.76	142	231
CSCN- 5	0.79	5.4	107	3.62	129	172
CSCN- 6	0.96	5.3	109	3.97	144	187
CSCN- 7	1.17	5.1	107	4.69	121	199
CSCN- 8	1.33	5.3	108	5.06	134	246
CSCN-9	1.21	5.4	108	4.73	130	204
CSCN-10	1.38	5.3	109	4.67	125	231
CSCN- 11	1.13	5.2	110	4.34	128	200
CSCN- 12	0.79	5.0	110	3.95	134	163
CD (5%)	0.17	NS	NS	0.18	14.2	25.1
			AVT			
CSCN-13	1.04	5.2	109	4.10	127	208
CSCN-14	1.17	5.3	110	4.20	131	227
CSCN-15	1.72	5.6	109	4.41	141	265
CSCN- 16	1.13	5.7	107	4.13	130	220
CSCN- 17	1.18	5.5	108	3.96	137	224
CSCN- 18	1.63	5.4	110	4.23	132	257
S.Em $\pm$	0.12	0.3	0.4	0.04	2.6	10.5
CD (5%)	0.38	NS	1.5	0.15	8.4	33.2

Table 196. Chemical characteristics of the soil after harvest of mustard (IVT 2009-10)

Soil depth (cm)	Before sowing		At harvest	
	pH_s	EC_e (dS/m)	pH_s	EC_e (dS/m)
0-15	8.19	0.50	8.22	2.85
15-30	8.30	0.47	8.33	2.71
30-45	8.32	0.43	8.36	2.54
45-60	8.33	0.44	8.39	2.16
60-90	8.35	0.46	8.43	1.96

Table 197. Chemical characteristics of the soil after harvest of mustard (AVT 2009-10)

Soil depth (cm)	Before sowing		At harvest	
	pH_s	EC_e (dS/m)	pH_s	EC_e (dS/m)
0-15	8.29	0.49	8.31	2.87
15-30	8.34	0.51	8.39	2.65
30-45	8.38	0.47	8.42	1.92
45-60	8.28	0.43	8.35	1.61
60-90	8.35	0.44	8.40	1.42

Data in regard to plant population, plant height, number of branches/plants, number of pods/plant, test weight and seed yield of mustard were recorded and is depicted in Table 198.

The seed yield of genotype varied from 0.55 t/ha of genotype CSCN 08-12 to 1.23 t/ha of CSCN 08-08 and 0.62 t/ha of CSCN 09-10 to 1.62 t/ha of CSCN 09-12 during 2008-09 and 2009-10 respectively.'

Table 198. Evaluation of salinity/alkalinity tolerance lines of rapeseed mustard

S. No.	Lines (2008-09)	Seed yield (t/ha)	S. No.	Lines (2009-10)	Seed yield (t/ha)
1.	CSCN 08-01	0.80	1.	CSCN 09-01	1.24
2.	CSCN 08-02	0.75	2.	CSCN 09-02	0.64
3.	CSCN 08-03	1.00	3.	CSCN 09-03	1.46
4.	CSCN 08-04	0.60	4.	CSCN 09-04	1.23
5.	CSCN 08-05	0.72	5.	CSCN 09-05	1.48
6.	CSCN 08-06	1.22	6.	CSCN 09-06	1.21
7.	CSCN 08-07	1.10	7.	CSCN 09-07	0.99
8.	CSCN 08-08	1.23	8.	CSCN 09-08	0.98
9.	CSCN 08-09	1.20	9.	CSCN 09-09	0.86
10.	CSCN 08-10	0.85	10.	CSCN 09-10	0.62
11.	CSCN 08-11	0.85	11.	CSCN 09-11	0.79
12.	CSCN 08-12	0.55	12.	CSCN 09-12	1.60
13.	CSCN 08-13	0.60	13.	CSCN 09-13	0.71
14.	CSCN 08-14	1.00	14.	CSCN 09-14	0.97
15.	CSCN 08-15	0.65	15.	CSCN 09-15	0.74
16.	CSCN 08-16	0.90	16.	CSCN 09-16	1.27
17.	CSCN 08-17	1.00	17.	CSCN 09-17	1.43
18	CSCN 08-18	0.90	18	CSCN 09-18	1.58
19	CSCN 08-19	1.10	-	-	-
20	CSCN 08-20	1.21	-	-	-
21	CSCN 08-21	0.82	-	-	-
	CD (5%)	0.16	-	-	0.14

Screening of Crop Varieties for Salt Tolerance - Bapatla

Maize

Four maize hybrids were screened for different levels of EC viz., Best Available Water (BAW), 2, 4, 6, 8 and 10 EC_{iw} and data on per cent germination were recorded. The data revealed that among different hybrids, 30V92 recorded the highest germination percentage (76.7%) followed by DH-117 (76.2%), Sandhya (61.7%) and Suvarna (59.8%). Among different levels of EC_{iw}, highest germination percentage was observed at BAW (95.3%) while lowest percentage was at 10 EC_{iw} (39.8%). In general, as the salinity increased the percentage of germination decreased (Table 199).

Table 199. Effect of different levels of salinity on germination of maize varieties

Maize varieties	EC of irrigation water (dS/m)						
	BAW	2	4	6	8	10	Mean
Suvarna	95	84	60	52	38	30	59.8
Sandhya	96	92	64	62	32	24	61.7
30V92	94	86	84	62	74	60	76.7
DH-117 (ANGRAU)	96	86	86	88	56	45	76.2
Mean	95.3	87.0	73.5	66.0	50.0	39.8	--

Bengal gram

Bengal gram variety (JG-110) occupies a large area in Prakasam, Guntur and Nellore districts under cultivation. The data revealed that germination at BAW was 92 per cent followed by 82 per cent at 2 dS/m, 75 per cent at 4, 68 per cent at 6, 59 per cent at 8 and 42 per cent at EC_{iw} of 10 dS/m.

Tolerance of Cotton Varieties to Saline Water Irrigation under Drip System - Bikaner

In non command area, tube well is the only source of irrigation. The productivity of groundnut is decreasing day by day due to increasing soil salinity as a result of irrigation with saline ground water, attack of insects, pests and soil born diseases and lack of appropriate crop rotation. Cotton is an alternative crop for use of poor quality water. Since drip irrigation has added advantage of using saline water, therefore, there is need to identify suitable varieties of cotton and optimum irrigation schedules for cotton in the zone under drip irrigation.

It is evident from Table 200 that methods of irrigation, salinity of irrigation water and varieties showed significant effect on seed cotton yield. Drip method was found significantly superior to flood method. Seed cotton yield was 44.2 per cent higher in drip as compared to flood irrigation. As far as salinity of water is concerned seed cotton yield decreased significantly at EC_{iw} 6.0 dS/m as compared to canal water and saline water having EC_{iw} 3.0 dS/m. However, differences in seed cotton yield with canal water and saline water of EC_{iw} 3.0 dS/m were not significant. The variety Bt cotton was significantly superior to other varieties.

Table 200. Effect of irrigation methods, salinity of water and varieties on seed cotton yield

Treatments	Seed cotton yield (t/ha)		Plant height (cm)		No. of bolls/ plant		Boll size (cm)	
	2009	2010	2009	2010	2009	2010	2009	2010
Methods of irrigation								
M_1-Drip	1.86	2.78	149.5	120.1	50.3	67	4.15	3.98
M_2-flood	1.29	1.97	107.0	106.8	44.0	58	3.87	3.77
S Em $\pm$	0.03	0.06	2.2	1.9	0..9	1.0	0.05	0.06
CD (5%)	0.10	0.16	6.2	5.5	2.5	2.9	0.14	0.17
Salinity of water								
S_1- 0.25 dS/m	1.78	3.05	135.5	128.6	54.0	83	4.26	4.30
S_2- 3.0 dS/m	1.69	2.35	129.4	117.3	48.0	67	4.11	4.15
S_3- 6.0 dS/m	1.27	1.73	120.1	94.6	39.0	37	3.66	3.68
S Em $\pm$	0.04	0.05	2.7	2.4	1.1	1.2	0.06	0.07
CD (5%)	0.12	0.13	7.6	6.8	3.0	3.5	0.17	0.20
Varieties								
V_1- F 846	1.35	1.81	124.3	110.7	46.1	55	4.07	4.11
V_2- RST-9	1.46	2.47	133.6	114.3	49.5	64	4.23	4.25
V_3-RG-8	1.35	2.21	120.2	107.5	41.7	61	3.45	3.47
V_4- Bt Cotton	2.15	3.02	135.3	121.4	51.2	68	4.28	4.30
SEm $\pm$	0.05	0.07	3.1	2.8	1.2	1.4	0.07	0.09
CD (5%)	0.13	0.19	8.8	7.8	3.5	4.1	0.20	0.26
CV (%)	12.7	11.8	10.3	10.3	11.1	9.7	7.4	7.9

Interaction between methods of irrigation and salinity of water on seed cotton yield was found significant (Table 201). Seed cotton yield decreased significantly at EC_{iw} 6.0 dS/m in both the method of irrigation. The minimum seed cotton yield was recorded at EC_{iw} 6.0 dS/m in flood method of irrigation. Interactive effect of methods of irrigation and varieties indicate that Bt cotton produced significantly higher yield in both the method of irrigation. Variety RST-9 gave significantly higher yield than RG-8 in drip method of irrigation. F-846 produced minimum seed cotton yield in flood method of irrigation.

Effect of methods of irrigation, salinity of irrigation water and varieties on yield attributes were also found to be significant. Plant height, number of bolls/plant and boll size were significantly higher in drip method of irrigation as compared to flood method. Yield attributes decreased significantly at EC_{iw} 6.0 dS/m as compared to canal water and saline water having EC_{iw} 3.0 dS/m. The variety Bt cotton and RST-9 produced taller plants as compared to F-846 and RG-8. Number of bolls per plant and boll size was recorded higher in Bt cotton followed by RST-9. The lowest values of these parameters were recorded in variety RG-8 (Table 200).

Table 201. Interactive effect of methods of irrigation and salinity of water and between irrigation methods and varieties on seed cotton yield (t/ha)

Treatments	2008-09		2009-10	
	Drip (M_1)	Flood (M_2)	Drip (M_1)	Flood (M_2)
Salinity of water				
S_1- 0.25 dS/m	2.12	1.10	3.37	2.74
S_2- 3.00 dS/m	2.04	0.94	2.87	1.82
S_3- 0.25 dS/m	1.43	0.74	2.11	1.35
S Em ± (MxS)	0.06		0.08	
CD (5%)	0.16		0.23	
Varieties				
V_1- F 846	1.62	1.07	2.08	2.08
V_2- RST-9	1.69	1.24	2.85	1.85
V_3-RG-8	1.47	1.23	2.57	1.55
V_4- Bt cotton	2.67	1.63	3.62	2.42
S Em ± (MxV)	0.07		0.09	
CD (5%)	0.19		0.27	

Fig. 53. View of cotton crop under saline irrigation using drip method

Evaluation of different Crops for their Tolerance to Sodicity - Tiruchirapalli

Crops *viz*. rice (TRY 1, CO 42, TRY(R)2, ADT 39, ADT 45, White Ponni), black gram (T9 and ADT 5), green gram (Pusa Bold), okra (Parbani Kranti), vegetable cowpea (VBN 37), cluster bean (Pusa Nowbuhar), sunflower (CO4, TCSH 1), sesame (CO1), and pearl millet (CO7, COHCu8, UCC23, UCC17, ICMY221, PT1890) were screened for sodicity tolerance and their tolerance limits have been established under this project. In continuation with the above research further green gram and maize varieties were selected for screening sodicity tolerance during 2008 to 2010.

The experimental soil was clay loam in texture with initial pH of 8.6, EC 0.43 dS/m, CEC 21 cmol (p+) /kg and an ESP of 16. The water used for irrigation was highly alkali with pH of 9.0, EC 1.65, RSC 10.5 and SAR 10.7. Taxonomically the soil of the experimental field belongs to fine, mixed, calcareous isohyperthemic Vertic Ustropept. The crops were grown in sodic soil with artificially created ESP gradients. The experiment on green gram and maize sequence was initiated during 2008 using split-plot design (SPD) with three replications

Main plots treatments : ESP levels (4) ESP 8, 16, 32 and 48. Adjusted ESP levels after application of gypsum/sodium bicarbonate were M_1= 9.2; M_2 = 18.4; $M_{3=}$ 29 and $M_{4=}$ 36

In sub plots treatment Green gram varieties S1: Vamban 2, S2: CO 6 and S3: CO 7 and Maize varieties S1: CO1, S2: COHM5 and S3:C818 were grown.

The green gram variety CO6 recorded the maximum yield of 603 kg/ ha and VBN 2 recorded the lowest seed yield of 416kg/ ha at ESP of 9.2. Among the different varieties tested, the variety CO6 recorded the highest mean yield of 428 kg/ ha followed by CO7 (377 kg/ ha) and VBN 2 (313 kg/ ha) and the yield of each variety differed significantly. Among the different ESP levels tried, the ESP 9.2 significantly recorded the maximum yield of 521 kg/ ha compared to other three levels.

In general the interaction between the green gram varieties and ESP levels showed that there was an increase in the yield of the three varieties significantly at the ESP level of 9.2 compared to the ESP of 18.4, 29 and 36 (Fig. 54 and Table 202). Irrespective of the varieties tested, the yield significantly reduced as the ESP level increased from 9.2 to 36.0. Although the yield levels vary yet similar results were obtained during 2009.

After harvest of the green gram, different maize varieties were sown in the same field (plot). Amongest the maize varieties, hybrid C818 produced an average yield of 2078 kg/ha, which was significantly different from other varieties viz., CO1 (1452 kg/ha) and COHM5 (941 kg/ha). The highest mean yield was registered at ESP 9.2 (2799 kg/ha) which reduced to 649 kg/ha at the ESP 36. The hybrid C818 recorded the maximum yield of 3856 kg/ha and hybrid COHM5 recorded the lowest yield of 1754 kg/ha at the ESP 9.2. The hybrid C818 performed well at all the ESP levels compared to other varieties as the ESP increased from 9.2 to 36 (Table 203).

During 2010, hybrid C818 produced a yield of 1757 kg/ha which significantly differed from other varieties viz., CO1 (1139 kg/ha) and COHM5 (646 kg/ha). The highest mean yield was registered at ESP 9 (2466 kg/ha) which reduced to 365 kg/ha at the ESP 35. At ESP 9 the maximum yield (3514kg/ha) was recorded by the hybrid C818 and the hybrid COHM5 recorded the lowest yield of 1412kg/ha. The hybrid C818 recorded significantly higher yield at all ESP levels compared to other maize varieties and hybrid (Table 203).

At all ESP levels, the highest Na to K ratio was found in roots of green gram varieties and stalks of maize variety and hybrids and the ratio increased with increasing ESP levels (Table 204). The plant height and No.of pods per plant for green gram varieties were higher at lower ESP levels compared to higher ESP levels. Similarly, in the maize varieties and hybrids also the plant growth and yield parameters viz., plant height, cob length and no. of grain lines per cob recorded higher values at low than at higher ESP levels.

The pre sowing and post harvest soil samples collected and analysed for pH, EC in green gram–maize sequence revealed that there was a decrease in the soil pH after green gram and maize crop compared to pre-sowing soil pH levels and also EC of the soil both during 2008-2009 and 2009-2010. The reduction in soil pH is mainly attributed to the use of canal water and reduction in EC might be due to leaching of salts due to summer showers received during the crop growth period.

The green gram yield data recorded during 2008 and 2009 were described using Mass and Hoffman's equation to find out the threshold ESP levels.

Mass Hoffman's Equation

Y_T (%) =100 –b (ESP_e-ESP_t)

Where,

Yt : relative yield at a sodicity level
b : slope of yield reduction curve (% yield loss per unit increase in sodicity beyond the threshold)
ESP_t : threshold soil sodicity after which yield begins to decline

The threshold ESP_t was found to be 9.7 for VBN2, 9.8 for CO6 and 9.7 for CO7 (2008). Whereas, during 2009 threshold ESP_t were 9.9 for VBN2, 9.7 for CO6 and 9.7 for CO7. The results indicate that green gram is quite sensitive among the 3 varieties tested, threshold ESP_t is around 10

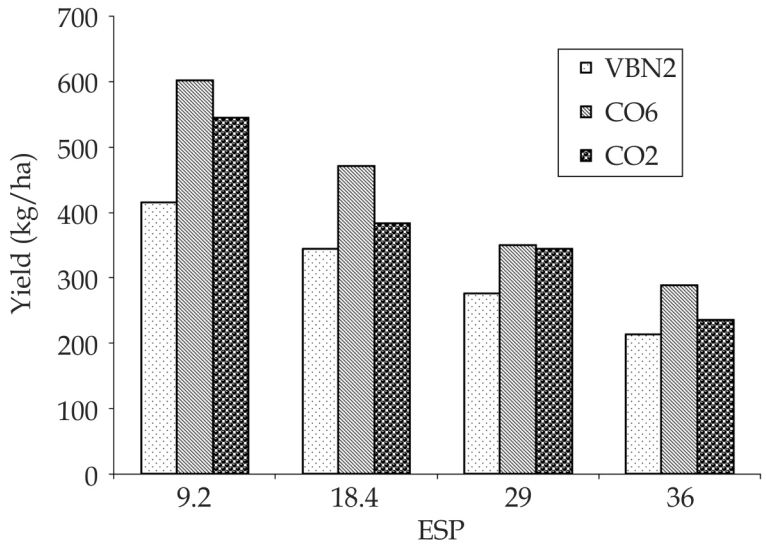


Fig. 54. Yield of green gram varieties at different ESP levels

Table 202. Yield of green gram varieties under different ESP levels during 2008 and 2009

2008					2009				
ESP levels	VBN2	CO6	CO7	Mean	ESP levels	VBN2	CO6	CO7	Mean
9.2	416	603	546	521	9	392	579	513	495
18.4	345	472	384	400	17	322	449	361	377
29.0	276	350	344	323	28	254	331	323	303
36.0	214	289	236	246	36	198	270	217	228
Mean	312	428	236		Mean	291	407	353	
	M	S	MxS	SxM	M	S	MxS		SxM
CD (5%)	12	17	28	32	6	4	9		8

Table 203. Yield of maize varieties under different ESP levels during 2008-09 and 2009-10

2008-09					2009-10				
ESP levels	CO1	COHM5	C818	Mean	ESP levels	CO1	COHM5	C818	Mean
9.0	2786	1754	3856	2798	10	2474	1412	3514	2466
17.0	1496	956	2176	1542	18	1182	656	1876	1238
30.0	896	612	1399	969	29	554	311	1099	655
39.0	629	440	879	649	38	345	207	542	365
Mean	1451	940	2077		Mean	1139	646	1757	
	M	S	MXS	SXM	M	S	MXS	SXM	
CD (5%)	44	51	89	96	158	58	184	117	

Table 204. Na/K ratio of green gram and maize varieties under different ESP levels

Na/K ratio (2008-09) (Green gram)												
ESP levels	VBN2				CO6				CO7			
	Seed	Root	Shoot	Mean	Seed	Root	Shoot	Mean	Seed	Root	Shoot	Mean
9.2	0.22	0.39	0.35	0.32	0.24	0.43	0.36	0.34	0.24	0.45	0.37	0.35
18.4	0.25	0.42	0.37	0.35	0.28	0.54	0.39	0.4	0.27	0.54	0.4	0.40
29.0	0.31	0.55	0.41	0.42	0.33	0.56	0.46	0.45	0.32	0.55	0.44	0.44
36.0	0.34	0.58	0.49	0.47	0.35	0.59	0.53	0.49	0.36	0.58	0.51	0.48
Mean	0.28	0.49	0.41		0.3	0.53	0.44		0.30	0.53	0.43	
Na/K ratio (2009-10)												
9.0	0.28	0.41	0.4	0.36	0.3	0.44	0.41	0.38	0.3	0.46	0.42	0.39
17.0	0.31	0.44	0.42	0.39	0.33	0.54	0.44	0.44	0.32	0.54	0.45	0.44
28.0	0.36	0.55	0.45	0.45	0.38	0.56	0.5	0.48	0.37	0.55	0.48	0.47
36.0	0.38	0.57	0.52	0.49	0.39	0.59	0.56	0.51	0.4	0.58	0.54	0.51
Mean	0.33	0.49	0.45		0.35	0.53	0.48		0.35	0.53	0.47	
Na/K ratio (2008-09) (Maize)												
ESP levels	CO1				COHM5				C818			
	Seed	Root	Stalk	Mean	Seed	Root	Stalk	Mean	Seed	Root	Stalk	Mean
9.0	0.48	0.61	0.64	0.58	0.46	0.59	0.64	0.56	0.49	0.62	0.65	0.59
17.0	0.54	0.63	0.66	0.61	0.52	0.62	0.66	0.60	0.52	0.65	0.66	0.61
30.0	0.49	0.63	0.69	0.60	0.48	0.66	0.67	0.60	0.49	0.65	0.69	0.61
39.0	0.51	0.67	0.69	0.62	0.51	0.67	0.69	0.62	0.54	0.69	0.69	0.64
Mean	0.51	0.64	0.67		0.49	0.64	0.67		0.51	0.65	0.67	
Na/K ratio (2009-10)												
10.0	0.5	0.6	0.6	0.57	0.48	0.59	0.61	0.56	0.51	0.6	0.6	0.57
18.0	0.56	0.61	0.62	0.60	0.54	0.6	0.63	0.59	0.53	0.63	0.61	0.59
29.0	0.51	0.63	0.65	0.60	0.5	0.65	0.64	0.60	0.51	0.65	0.65	0.60
38.0	0.53	0.68	0.65	0.62	0.52	0.66	0.65	0.61	0.55	0.68	0.65	0.63
Mean	0.53	0.63	0.63		0.51	0.63	0.63		0.53	0.64	0.63	

E. ON-FARM TRIALS AND OPERATIONAL RESEARCH PROJECTS

- Operational Research Project on Improvisation and Demonstration of Reclamation Technologies for Black Alkali Soils (Bapatla)
- Operational Research Project on the Use of Poor Quality Ground Water (Agra)
- Low Cost Technology for Dilution of Saline Ground Water through Artificial Recharge (Agra)
- Skimming Well Technology and other Alternative Technologies for development of Water Resources in Coastal Sandy Soils (Bapatla)
- Effect of Gypsum Application on Crop Production and Soil Chemical Environment (Indore)
- Field Trials conducted on Farmer's Field (Hisar)

Operational Research Project on Improvisation and Demonstration of Reclamation Technologies for Black Alkali Soils – Bapatla

During 2008-09 the technology was successfully demonstrated at 6 locations i.e., Kondamuru-I & II, JV palem-I, II, Kasyapuram, Renangivaram in Prakasam district. Gypsum was applied as per soil test value (Table 205) and *Dhaincha* was grown and ploughed *in-situ* at 50% flowering. $ZnSO_4$ was applied as basal @50kg/ha, N-P_2O_5 –K_2O @ 180-60-40 kg/ha (N-50% extra). The paddy was transplanted with variety NLR – T-145 under NSP canal area. The initial soil analysis data indicated that the pH_s ranged from 9.0 to 9.6, EC_e ranged from 2.1 to 5.8, available N was low and P was medium and K was high in status. The texture was clayey. At one site Bengal gram (var. JG-11) was sown during *rabi*, 2008. The results indicated that application of gypsum increased the grain yield of paddy by 19.5 to 29.4% and Bengal gram by 23.8% over control (Table 206).

Table 205. Initial soil status of different locations for reclamation of alkali soils (2008-09)

Name of the farmer	Village	Cropping system	EC_e (ds/m)	pH_s	N	P_2O_5	K_2O
					kg/ha		
J. Venkataswarlu	J.V.Palem	Rice --Fallow	3.1	9.3	209	29	494
P. Nageswararao	J.V.Palem	Rice --Fallow	2.2	9.0	230	30	448
Ch. Nagalakshmi	J.V.Palem	Rice --Fallow	2.1	9.2	251	32	464
M. Narapa Reddy	Kondamur	Rice --Fallow	5.8	9.4	219	31	411
K. Umamaheswarao	Kasyapuram	Rice --Fallow	2.2	9.6	230	318	408
V. Subbarao	Chavatapalem	Fallow-Bengal gram	2.2	9.2	252	32	337

Table 206. Effect of gypsum on grain yield (t/ha) of paddy and Bengal gram in alkali soils (2008-09)

Name of the farmer	Village	Control	Gypsum applied	% increase in yield
		Rice grain yield (t/ha)		
J. Venkataswarlu	J.V.Palem	4.38	6.20	29.4
P. Nageswararao	J.V.Palem	4.63	5.75	19.5
Ch. Nagalakshmi	J.V.Palem	4.12	5.20	20.1
M. Narapa Reddy	Kondamur	3.57	4.51	20.8
K. Umamaheswarao	Kasyapuram	4.50	6.10	25.9
		Bengal gram seed yield (t/ha)		
V.Subbarao	Chavatapalem	1.25	1.64	23.8

During 2009-10, the demonstrations were laid out at 3 locations. The initial pH_s ranged from 9.4 to10.0 and EC_e from 1.38 to 4.57 dS/m, available N was low, P_2O_5 was medium and high in potash, ESP from 14.5 to 19. The grain yield of rice ranged from 3.23 to 4.71 t/ha in gypsum treated plots as compared to 2.30 to 2.65 t/ha in control (Table 207). The per cent increase was from 17.8 to 45.4. The final soil analysis indicated that the soil pH_2 ranged from 8.2 to 8.9 and showed reduction over initial soil values. The EC_e also decreased. The available N, P_2O_5, K_2O status of the soil increased over initial status.

Table 207. Effect of gypsum on grain yield of rice (variety NLR-9674) (2009-10)

Name of the farmer	Village	Cropping system	Gypsum applied (t/ha)	Yield (t/ha)		Per cent increase
				Treated	check	
I. Rajeswara Rao	Konidana	Rice - Fallow	15.5	3.23	2.65	17.8
K. Venkateswarlu	Gangapalem	Rice - Fallow	10.0	4.71	2.58	45.4
K. Sivaiah	Gangapalem	Rice - Fallow	13.3	3.87	2.30	40.7

Operational Research Project on the Use of Poor Quality Ground Water –Agra

The field demonstrations in operational research project for the use of poor quality water were initiated during kharif 1993 and continued during 2008-09 and 2009-10. The selected farmers were grouped on the basis of most suitable management options to be implemented at fields (Table 208).

Table 208. Grouping of farmers on the basis of management options

Group	Number of farmers		Water quality problem	Strategy for management
	2008-09	2009-10		
A	6	7	Alkalinity	RSC management with gypsum
B1	2	2	High Salinity	Conjunctive use of low salinity with high salinity water
B2	1	-	High Salinity	Pearl millet-Wheat/Barley
B3	6	6	High Salinity	With post sowing sprinkler irrigation or Dhaincha GM/Sorghum Fodder - Mustard with rain conserved moisture
C	10	10	Saline and alkaline	Crop and fertilizer management

The quality parameters pertaining to well waters of the selected farmers are given in Table 209. During the year, 2008-09, 2009-10, demonstrations were conducted at 25 farmers field during both the years. The selections of farmers was based on the availability of alkali, saline and canal water and necessary infrastructural facilities. Gypsum was added on the basis of the soil tests. The water quality parameters pertaining to tubewell water of the selected farmers are given in Table 2. During these years, the salinity of RSC water varied from 2.7-5.1 dS/m, RSC 6.2 – 12.0 meq/l and SAR 16.0 -25.8 $(mmol/l)^{1/2}$. In saline water at Odara and Nagla Parasuram ECiw varied from 6.0 -23.5 dS/m and SAR 11.0-30.0 $(mmol/l)^{1/2}$.

Table 209. Water quality of tube wells

Name of the farmer	EC_{iw}	RSC (meq/l)	SAR $(mmol/l)^{1/2}$
RSC water			
Mr. Rajesh Kumar	3.0	8.8	17.0
Mr. Krapa Shanker	3.0	8.8	17.0
Mr.Om Prakash	4.4	7.6	23.9
Mr. Hari Shanker	3.9	12.0	25.8
Mr. Hakim Singh	5.1	6.2	24.7
Mr. Vijay Dixit	3.5	12.0	19.0
Mr. Satya Prakash	2.7	11.8	16.0
Saline Water			
Mr. Subhash Chand	10.0	-	11.0
Mr. Balveer Singh	11.8	-	13.9
Mr. Amar Chand	13.5	-	12.5
Mr. Ram Bharosee	15.0	-	19.0
Mr. Hari Prasad	13.5	-	12.5
Mr. Lal Hans	10.9	-	16.2
Mr. Dinesh Chand	11.0	-	17.0
Mr. Mukesh Kumar	13.8	-	24.0
Mr. Roop Singh	23.5	-	24.9

Mr. Virendra Singh	19.9	-	13.1
Mr. Jagan Singh	12.6	-	15.5
Mr. Dal Chand	12.5	-	17.3
Mr. Shiv Kumar	12.5	-	17.3
Mr. Munsi lal	12.0	-	13.8
Mr. Rohan Singh	13.2	-	23.3
Mr. Narayan Singh	6.0	-	13.1
Mr. Mukesh	15.2	-	13.2
Mr. Bharat Singh	13.2	-	23.3
Mr. Dara Singh	23.0	-	30.0

Management of alkali water

During 2008-10, gypsum trials were conducted in the ORP. Gypsum was added in 6 farmer's field, having alkali water. Gypsum was applied on the basis of 50%GR and pearl millet was cultivated with flat sowing. The yield increased by 8.8 to 14.3% with incorporation of gypsum as a consequence of decrease in pH, SAR and ESP (Table 210). Similar results were obtained with cotton (Table 211) and wheat (Table 212).

Table 210. Effect of gypsum on pearl millet yield and soil characteristics in alkali water irrigation

Name	Treatment	Average yield (t/ha)	Per cent increase over control	Soil characteristics at harvest (0-30 cm)			
				EC_e (dS/m)	pH_2	SAR	ESP
Sh. Krapa Shankar	50% GR	2.23	14.5	2.3	8.6	8.0	9.7
	No gypsum	1.95	-	2.6	8.9	12.4	14.6
Sh. Om Prakash	50% GR	2.17	14.0	2.1	8.7	9.7	11.7
	No gypsum	1.89	-	2.2	8.9	10.4	15.1
Sh. Raj Kumar	50% GR	1.60	8.8	2.1	8.8	12.6	17.3
	No gypsum	1.47	-	2.0	9.0	15.8	21.8
Sh. Hakim Singh	50% GR	2.1	12.9	4.6	8.5	17.3	20.4
	No gypsum	1.8	-	4.4	8.8	19.0	22.7
Sh. Vijay Dixit	50% GR	1.92	14.3	3.4	9.0	17.6	25.6
	No gypsum	1.68	-	3.7	9.3	20.7	29.9
Sh. Satya Prakash	50% GR	2.41	14.1	3.8	8.5	15.9	19.2
	No gypsum	2.12	-	4.4	9.0	17.8	23.3

Table 211. Effect of gypsum application on cotton (RG-8) yield

Name	Treatment	Yield (t/ha)	Per cent increase over control	Soil characteristics at harvest (0-30 cm)			
				EC_e (dS/m)	pH_2	SAR	ESP
Sh. Kripa Shankar	50% GR	0.62	12.8	1.9	8.6	8.2	9.8
	No gypsum	0.55	-	1.5	8.7	9.0	10.8
Sh. Rajesh Kumar	50% GR	0.67	13.5	2.6	8.7	14.3	17.2
	No gypsum	0.59	-	2.1	8.8	10.8	13.3
Overall			13.1				

Table 212. Effect of gypsum on wheat yield and soil characteristics (0-30 cm) at harvest

Name	Treatment	ORP yield (t/ha)	% increase over control	EC_e (dS/m)	pH_2	SAR	ESP
Mr. Krapa Shankar	Gypsum	4.07	-	4.0	8.6	16.0	20.9
	No gypsum	3.75	8.7	4.2	8.7	18.5	25.5
Mr. Rajesh kumar	Gypsum	4.15	-	4.0	8.7	16.0	20.9
	No gypsum	3.87	7.1	4.2	8.9	18.1	25.8
Mr. Om Prakash	Gypsum	4.05	-	7.0	8.7	25.5	33.1
	No gypsum	3.82	5.9	7.0	8.8	27.1	35.7
Mr. Hakim Singh	Gypsum	3.77	-	11.5	8.7	26.1	31.6
	No gypsum	3.52	7.1	11.5	8.9	28.6	38.4
Mr. Vijay Dixit	Gypsum	3.95	-	7.7	9.2	21.9	28.9
	No gypsum	3.55	11.3	8.0	9.3	28.0	36.5
Mr. Satya praksh	Gypsum	4.45	-	3.8	8.8	16.6	21.4
	No gypsum	4.05	9.9	3.7	9.2	18.1	25.0
Mr. Rajesh Kumar	Bed Sowing	3.36	-	4.4	8.7	19.2	25.6

Conjunctive use of low salinity water/ high salinity water

The conjunctive use of low and high salinity water was demonstrated on three farmer's field during 2008-10 (Table 213). During this period different irrigation modes i.e. 2LSW + RTS and LSW showed yield improvement which ranged from 9.4 – 10.3 per cent in ORP when compared with conventional farming. The soil salinity and SAR varied from 7.1 to 20.1 dS/m and 18.1 to 21.7 $(mmol/l)^{1/2}$.

Table 213. Conjuctive use of low salinity water / high salinity water

Name	Treatments		Wheat variety	Av. ORP yield (t/ha)	Av. Conv. yield (t/ha)	% increase in ORP	EC_e (dS/m)	pH_2	SAR
	2008-09	2009-10							
Sh. Dal Chand	2LSW+ RTS	2LSW+ RTS	PBW 343	5.12	4.65	10.1	10.8	8.0	21.7
Sh. Narayan Singh	LSW	LSW	PBW 343	5.3	4.7	9.4	7.2	7.3	18.1
Sh. Subhash Chand	2LSW+ RTS	2LSW+ RTS	Lok-1	5.29	4.74	10.3	9.5	7.4	19.2

LSW- Low Salinity Water (EC_{iw} 4-6 ds/m); RTS – Rest Tube well Saline water

Comparison of post sowing sprinkler with conventional pre sowing saline irrigation

On farmer field wheat crop was sown in dry soil and sprinkler irrigation was applied to improve the seed emergence with saline water irrigation (Table 214). The wheat yield increased by 10.1% in post sowing sprinkler irrigation over pre sowing saline irrigation (conventional farming).

Table 214. Comparison of post sowing sprinkler with pre sowing saline irrigation (2008-09)

Name	Wheat variety	ORP yield (t/ha)	Conventional yield (t/ha)	Per cent increase	EC_e (dS/m)	pH_2	SAR
Sh. Amar Chand	PBW-343	3.57	3.25	9.8	15.5	7.5	16.5
	Lok-1	5.30	4.8	10.4	13.5	7.1	17.0

Crop and fertilizer management

Crop sown in rain conserved moisture

On four farmer's field wheat was sown in conserved moisture to improve the seed emergence in saline condition and after that saline water was applied to the crop (Table 215). The wheat yield increased by 10.5 per cent over farmer's field where the saline water was used for pre-sowing and other irrigations.

Table 215. Effect of recharge water on yield of wheat and soil properties (0-30cm)

Name	Wheat variety	ORP Yield (t/ha)	Yield at farmers field (t/ha)	Per cent increase	EC_e (dS/m)	pH_2	SAR
Mr.Balbeer Singh	Lok-1	4.83	4.38	10.3	6.8	7.6	15.4
Mr. Hari Prasad	,,	4.95	4.46	11.3	1.7	7.1	20.7
Mr.Dinesh Chand	,,	4.41	4.02	9.7	5.2	8.1	11.0
Mr.Amar Chand	,,	5.08	4.57	11.2	8.7	7.4	17.9

Low Cost Technology for Dilution of Saline Ground Water through Artificial Recharge -Agra

Agra–Bharatpur region in the states of U.P. and Rajasthan are endowed with poor quality groundwater aquifers. Shallow aquifers are relatively more saline (10-15 dS/m) relative to deeper aquifers (2-6 dS/m). The resource poor farmers of the region who can not afford to drill deep bores are contented with exploiting the saline aquifers to give 1 or 2 life saving irrigation to mustard. Under such a situation, yields are reduced due to high salinity. Diluting saline groundwater through artificial recharge has been designed and tested on 12 farmer's fields. The technology consisted of diverting the runoff to these structures for recharge (Fig. 55). The diluted ground water is then pumped to irrigate mustard/wheat. The salinity of the groundwater is reduced in most cases to less than 4 dS/m but eventually reaches to its original value during 3rd or 4th irrigation. The irrigation with low quality water at initial growth stage boosts the yield to normal level in the case of mustard and wheat.

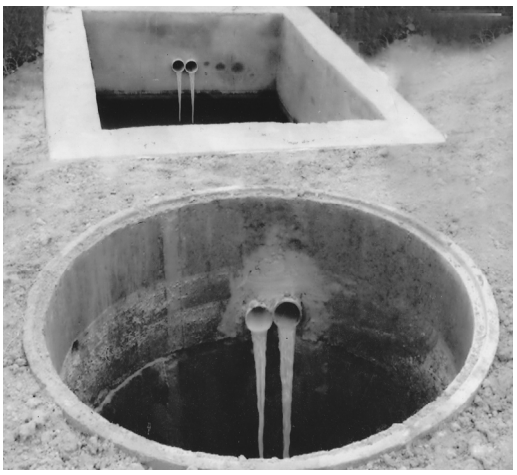


Fig. 55. Low cost technology for dilution of saline groundwater through artificial recharge

The demonstrations were conducted at 8 recharge sites and compared with farmer's practice during 2008-09. The wheat yield varied from 4.96 to 5.56 t/ha while on other farmer fields the yield varied from 4.58 to 5.15 t/ha with high salinity water. The per cent wheat yield increased by 8.1 on recharge sites over other farmer fields (Table 216).

Table 216. Effect of saline water on wheat and soil properties (0-30 cm) at recharge sites

Name	Wheat variety	ORP yield (t/ha)	Yield at farmer's field (t/ha)	Per cent increase	EC_e (dS/m)	pH_2	SAR
Sh. Balveer Singh	LOK-1	5.56	-	8.0	9.9	7.7	14.1
	,,		5.15	-	-	-	-
Sh. Hari Prasad	PBW-373	5.33		7.7	14.7	7.2	17.5
	LOK-1	-	4.95	-			
Sh. Jagan Singh	PBW-343	5.28	-	8.4	13.5	7.3	15.5
	,,	-	4.87	-			
Sh. Mukesh Kumar	LOK-1	5.25	-	8.7	5.3	7.3	14.1
	,,	-	4.83	-			
Sh. Ranveer Singh	PBW-373	5.41	-	7.5	13.6	7.4	24.6
	LOK-1	-	5.03	-			
Sh. Ram Bharose	LOK-1	5.40	-	7.6	15.0	7.5	25.3
	,,	-	5.02	-			
Sh. Lal Hans	Raj 3765	4.96	-	8.3	13.9	7.6	25.2
	Raj 3765	-	4.58	-			
Sh. Dinesh Chand	LOK-1	5.11	-	8.5	7.5	7.9	19.9
	,,	-	4.71	-			
Over all				8.1			

The average salinity of water at 8 recharge sites varied from 0.5 to 7.2 dS/m at first pre-sowing irrigation, 6.4 to 10.8 at second irrigation, 8.0 to 15.0 at 3rd irrigation and 9.4 to 17.0 at 4th irrigation (Table 217).

Table 217. Salinity of water (dS/m) during different irrigations at recharge sites

Name	Ist irrigation	IInd irrigation	IIIrd irrigation	IVth irrigation
Mr. Balveer Singh	0.5	7.7	10.3	13.7
Mr. Hari Prasad	6.1	10.5	16.1	17.0
Mr. Jagan Singh	0.5	8.3	9.3	9.4
Mr. Mukesh Kumar	4.7	10.2	14.1	15.0
Mr. Ranveer Singh	6.5	10.6	12.7	13.0
Mr. Ram Bharose	7.2	10.8	15.0	16.5
Mr. Lal Hans	5.0	10.2	12.2	13.0
Mr. Dinesh Chand	1.4	6.4	8.0	9.5

The demonstrations were conducted on 10 recharge sites during 2009-10. The wheat yield varied from 4.08 to 5.16 t/ha whereas on other farmers fields the yield varied from 3.68 to 4.67 t/ha which used high salinity water. The wheat yield increased by 10.5 per cent on recharge sites over other farmer's field. The soil salinity and SAR increased at harvest as per the quality of recharge water applied for the irrigation to wheat crop (Table 218).

Table 218. Effect of diluted saline water on wheat yield and soil properties at recharge sites

Name	Wheat variety	ORP yield t/ha	Farmers yield (t/ha)	Per cent increase	EC_e (dS/m)	pH_2	SAR
Mr. Jagan Singh	LOK-1	5.16	4.67	10.5	7.0	7.2	15.6
Mr. Mukesh Kumar	,,	4.66	4.21	10.7	8.3	7.5	15.0
Mr. Ram Bharosi	,,	4.74	4.23	10.2	7.5	7.6	18.1
Mr. Lal Hans	,,	4.50	4.07	10.6	9.2	7.9	22.1
Mr. Birendra Singh	PBW-343	4.24	3.85	10.1	10.2	7.3	20.9
Mr. Roop Singh	PBW-343	4.08	3.68	10.8	10.2	7.6	20.2
Over all				10.5			

Skimming Well Technology and other Alternative Technologies for development of Water Resources in Coastal Sandy Soils - Bapatla

AICRP Centre Bapatla installed 92 skimming wells covering an area of 198 ha in 25 villages in Prakasam, Guntur and West Godavari districts of Andhra Pradesh including 6 drinking water wells (Table 219). During the year watertable fluctuation and water quality were monitored at monthly interval in selected 25 skimming structures, 8 drains and irrigation channels in the Bapatla coast. The water table depth varied from 1.39 to 2.04 m at Bapatla and ground level to 1.79 m at Timmareddypalem. The EC of skimming well waters at Bapatla and Timmareddypalem varied from 0.16 to 0.54 dS/m and 0.77 to 0.90 dS/m respectively during 2008-09.

Continuous monitoring of pumped waters in selected vertical tube well (16' deep) at Pandurangapuram area during 2008-09 revealed that EC rose from 0.40 dS/m to 1.35 dS/m during April to September, 2008. This is an exceptional case near the sea coast and needs to be further investigated using the geo-physical techniques.

During the project period, feasibility studies were also carried out on installed skimming structures for saline water upconing. State of art multi-electrode imaging/geophysical studies, recharge studies, hydraulic performance test studies and socio-economic evaluation of skimming structures was made. The skimming studies revealed that the improved fresh water skimming techniques have promising future prospects for sustaining crop production along the coastal belts and serve to meet the drinking water needs of the coastal community.

Upconing and pumping strategies with shallow tube well

Whenever fresh ground water is underlain by saline water, pumping a well in fresh water zone causes the fresh salt water interface to rise (upconing) below the well. This 'upconing' is in response to the pressure reduction in the interface due to drawdown of the water table around the well. If the bottom of the well is close to the saline water or the well discharge is relatively high, the salt water cone may reach into the well, causing the well water to be a mixture of fresh and saline ground water.

Considering the influencing parameters such as the well discharge (Q), depth of fresh water-salt water interface below well bottom prior to pumping (L), hydraulic conductivity, both horizontal and vertical (K_x and K_z), porosity (n) of the aquifer and time since pumping started (t), Bear and Dagan (1968) presented an equation to calculate upconing and the same being modified for different situations.

The critical height generally varies between 0.4 to 0.6 times L. The rise of saline upcone (Zt) for different time intervals for general conditions and for 8 different location specific aquifer conditions was estimated for isotropic (K_h=K_v) and anisotropic (K_h/ Kv = 1.25, 2, 4, 8) situations. The upconing were estimated with different anisotropy ratios with the view that there will be variation in the vertical hydraulic conductivity as compared to horizontal hydraulic conductivity, which is generally true for layered soils. Based on the pumping drawdown of these locations, considering critical height of upconing, maximum permissible height of upconing, an impulse- response conceptual frame work of saline water upcone was developed and safe time of pumping was estimated for different locations. The data were utilized to assess the pumping schedule so saline water does not enter in the well. To achieve this, an equation was fitted between upconing and time for isotropic conditions, which resulted in the following linear relation.

$$Y_h = 0.3868\ t + 0.0486 \quad (1)$$

Where,

Y_h = Upconing height at centre of the well (or) Z_{crt} at any time t, m

t = Pumping time, hours

Similarly, for different anisotropic ratios, the estimated upconing equations were developed (Fig. 56). It reveals that after 8 hours of pumping, the height of upcone is 3.11 m, which exceeds the critical

height of upcone and saline water would enter into the well. But in reality, after 0.4 to 0.6 times of the critical height of upcone, the upconing is considered to rise abnormally. Keeping this in view, a maximum permissible limit was kept at 0.5 times the critical upconing by which upconing of 1.554 m takes place after 4 hours of pumping. Hence, the pumping under the present general situation should be limited to 4 hours.

Table 219. Collector wells installed under the technical assistance of AICRP Saline Water Scheme

Sl. No.	Name of the village	No. of collector wells	Area covered (ha)	Purpose/ crops grown
1	Bapatla	22	47	Paddy nursery, pulses, rabi groundnut / plantation crops
2	Vedullapalli	3	4	Rose nursery
3	Reddypalem	13	33	Mango and coconut nursery, paddy nursery, Rabi groundnut and aromatic plants
4	Muthaipalem	2	5	Forest crop nurseries
5	Keerthivaripalem	1	2	Rabi groundnut, vegetables and poultry
6	Kavuru	1	2	Different crop nurseries and vegetables.
7	Bavanamvaripalem	1	2	Vegetables and ground nut.
8	Ramabatlavaripalem	1	4	Paddy nursery and *rabi* groundnut
9	Padison peta	4	8	Paddy nursery, leafy vegetables, vegetables, watermelon and aquaculture
10	Khajipalem	1	1	Coconut and mango
11	G.N.Palem/ P.V.Palem	4	5	Paddy nursery, paddy, pulses and vegetables.
12	Chandolu	1	2	Paddy nursery, Paddy pulses and vegetables
13	Dammanavari palem	3	6	Rabi groundnut, vegetables and paddy
14	Manubroluvari palem	6	20	Paddy nursery, pulses, plantation crops, cattle and sheep farms.
15	Kothapalem	3	6	Paddy nursery, pulses and plantation crops.
16	Chinamatlapudi	1	1	Paddy nursery, pulses and groundnut.
17	Akkayapalem	1	2	Vegetables and paddy nursery.
18	Nagendrapuram	4	6	Groundnut, *Casurina* and Paddy
19	Pandillapalli	3	6	Paddy and vegetable crops
20	Yetigaddavaripalem	1	2	Groundnut, paddy nursery and pulses
21	Perupalem	1	4	Mango garden and vegetables
22	Vetapalem	2	6	Paddy nursery and *rabi* groundnut
23	Yajali	2	2	Groundnut /Groundnut-paddy nursery
24	Pandurangapuram	2	16	Groundnut/groundnut
23	Alakapuram, GN Palem, Alluru, Jonnavaripalem, Lakshmipuram and Shantinagar	6	-	Drinking water wells under rural drinking water scheme of Govt. of AP.
	Total	89	192	

Similar analysis for Muthaipalem showed that within 2 hours of pumping the height of upcone would be 2.08 m, which is also critical to reach the well bottom. As discussed earlier, keeping a maximum permissible limit of 0.5 times the critical upconing, upconing of 1.04 m was assessed after 1 hr of pumping. Hence, the pumping at Muthaipalem area should be limited to 1 hour under the given conditions. For higher pumping time, the pump discharge should be reduced from 4 lps to 2-3 lps for the existing wells. Reduction in penetration depth may also be a possible solution for new installations. The upcone response to the fresh water drawdown impulse at this location (Fig. 57) clearly indicated the upconing trend under the existing situation. For other locations studied, F_{cr} varied and the safe pumping time varied from 0 -13 hours (Table 220).

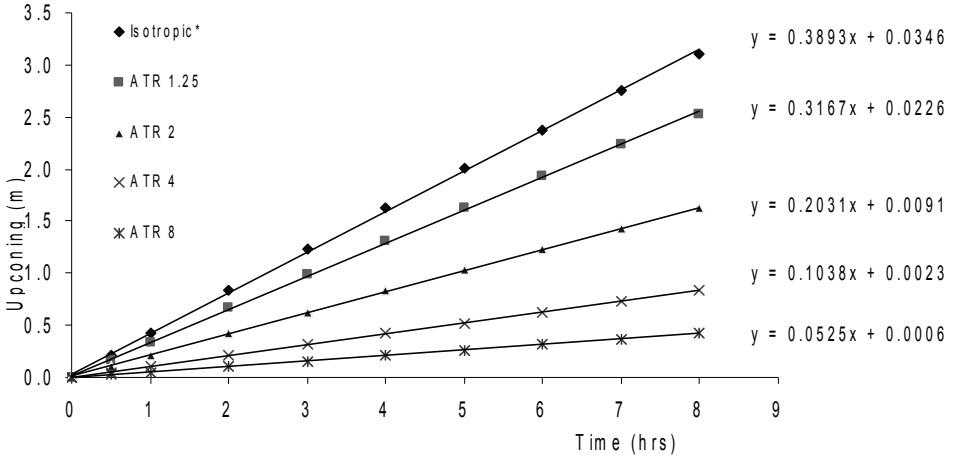


Fig. 56. Generalized upcone trends due to pumping under assumed field conditions for coastal sands

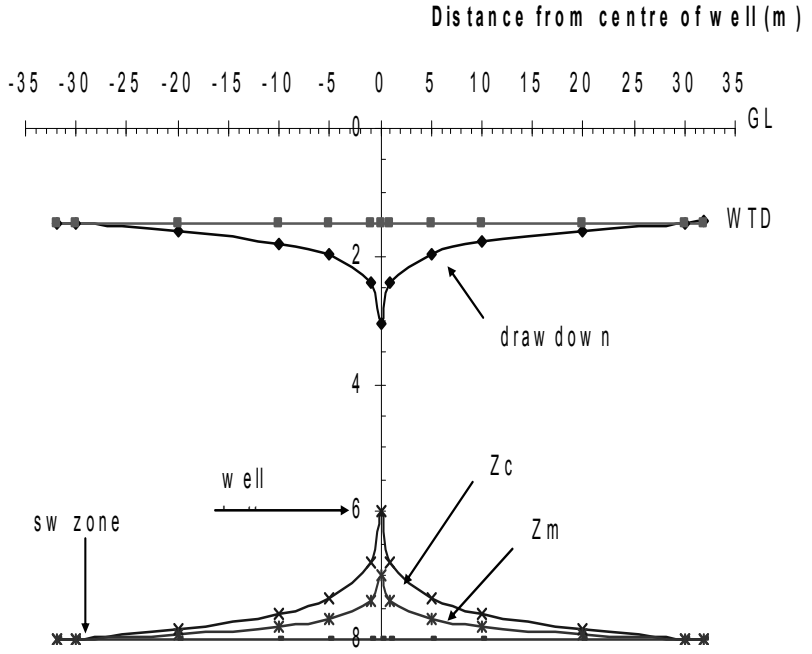


Fig. 57. Saline upconing response to fresh water drawdown impulse at Muthaipalem

Table 220. Upcone values for different locations with safe pumping time

Location	Upconing parameters				Safe pumping time (hrs)
	Z critical (m)	Z_{max} (m)	Fcr	Fs*	
Muthaipalem	2.00	1.00	0.790	0.5	1.0
Bapatla	2.00	1.00	0.815	0.5	1.0
Padisonpet	3.60	1.80	0.619	0.5	6.0
Karlapalem	3.20	1.60	0.419	0.5	11.0
T R Palem	1.90	0.95	0.732	0.5	1.0
RBV Palem	3.20	1.60	0.363	0.5	5.0
Kothapalem	4.50	2.25	0.191	0.5	13.0
P V Palem	0.50	0.25	-	0.5	NF

*NF : Not feasible for pumping; *Reduction factor range : 0.4 – 06*

Even as the inland aquifers are suffering from the maladies of over exploitation of ground water by way of unscrupulous pumping, the coastal aquifers encounter the danger of sea water intrusion and saline water upconing. Fresh water skimming is the only alternative in coastal zones to stabilize crop production.

The economic viabilities of skimming technologies were also ascertained in addition to their technical feasibilities. The economic appraisal of the improved technologies at farmer's level using discounting techniques revealed that skimming well with horizontal collectors contributes higher benefits to the farmers followed by multi-strainer tube well and shallow tube well technologies. Even under adverse situation of increase in costs and decrease in returns to a tune of 5 per cent each, the farmers will still reap the highest benefits under skimming well with collectors, as indicated by the values of NPW, B-C ration and IRR i.e. 52629, 2.01 and 33 per cent for the life of 25 years. The project was concluded during 2008-09.

Effect of Gypsum Application on Crop Production and Soil Chemical Environment - Indore

Gypsum was used as reclaiming agent to reclaim alkali soils. Demonstrations were carried out on 5 farmer's fields in two villages of districts Indore and Khargone of Malwa and Nimar agro-climatic zones.

Soybean-wheat crop rotation

The demonstrations on 5 Farmers Fields were conducted with soybean (variety JS 9560) and wheat (variety Lok-1). The details of farmers fields selected and date of sowing are given in Table 221. Gypsum was applied on the basis of gypsum requirement (GR) estimated in the laboratory for each farmer field separately before start of experiment. Necessary plant protection and inter-culture operations were adopted as per package of practices.The initial properties of the experimental soils (Table 222) revealed that soils are alkali in nature (ESP ranging from 24.9 to 27.9), clay in texture with high CEC. The gypsum requirement of different farmer's fields was in range of 10.3 - 13.8 t/ha.

The data in Table 223 and 224 revealed that application of gypsum significantly increased seed yield of soybean as well as grain yield of wheat over control. Application of gypsum @ 75% GR registered significant increase in yield over 25% GR. The differences between 50% GR and 75% GR were statistically non-significant.

Table 221. Details of the trials conducted on farmers field (Indore district)

Name of the farmer	Village	Tehsil	Area/plot (m^2)	Date of sowing of soybean	Date of sowing of wheat
			2008-09		
Sh. Babulal Harisingh	Agra	Depalpur	20x25	29.06.2008	25.11.2008
Sh. Mangilal Ramratan	Agra	Depalpur	20x25	27.06.2008	29.11.2008
Sh. Dinesh Prajapat	Sumtha	Depalpur	20x25	30.06.2008	27.11.2008
Sh. Motiram Pawar	Sumtha	Depalpur	20x25	30.06.2008	30.11.2008
Sh. Badrilal Prajapat	Sumtha	Depalpur	20x25	30.06.2008	21.11.2008
			2009-10		
Sh. Babulal Harisingh	Agra	Depalpur	20x25	27.06.2009	27.11.2009
Sh. Mangilal Ramratan	Agra	Depalpur	20x25	28.06.2009	29.11.2009
Sh. Dinesh Prajapat	Sumtha	Depalpur	20x25	01.07.2009	24.11.2009
Sh. Motiram Pawar	Sumtha	Depalpur	20x25	30.06.2009	26.11.2009
Sh. Badrilal Prajapat	Sumtha	Depalpur	20x25	30.06.2009	24.11.2009

Table 222. Initial soil properties of Farmers' field (2008-09)

Name of the farmer	pH_2	EC_2 (dS/m)	CEC (c mol(+)/kg)	ESP	GR (t/ha)
Sh. Babulal Harisingh Patel	8.3	1.39	39.4	25.1	11.7
Sh. Mangilal Ramratan	8.4	1.22	45.2	24.9	10.3
Sh. Dinesh Prajapat	8.3	1.50	40.0	27.9	13.8
Sh. Motiram Pawar	8.5	1.32	46.8	25.3	12.4
Sh. Badrilal Prajapat	8.4	1.25	42.5	26.1	12.4

Table 223. Effect of gypsum application on seed yield (t/ha) of soybean on farmer's field

Treatments	Name of the farmers					Mean
	Babulal	Mangilal	Dinesh	Motiram	Badrilal	
			2008-09			
Control	1.89	1.78	2.01	2.10	2.16	1.99
25% GR	2.07	1.93	2.26	2.19	2.37	2.16
50% GR	2.28	2.14	2.47	2.35	2.55	2.36
75% GR	2.21	2.23	2.37	2.42	2.47	2.34
CD (5%)						0.07
			2009-10			
Control	1.50	1.55	1.40	1.50	2.10	1.61
25% GR	2.00	1.90	2.20	2.25	2.35	2.14
50% GR	2.20	2.10	2.40	2.40	2.50	2.32
75% GR	2.25	2.25	2.40	2.45	2.50	2.37
CD (5%)						0.10

ESP values decreased with gypsum application as compared to untreated soil. Lowest values of ESP were observed under 75% GR which are statistically at par with 50% GR (Table 225).

Cotton

The demonstrations on farmer's fields were conducted with cotton as test crop. The details of farmer selected and date of sowing is given in Table 226. Necessary plant protection and inter-culture operations were adopted as per package of practices. Sowing was done at farmer's field with

recommended package of practices (seed rate - 8 kg/ha, nitrogen - 120, phosphorus - 60 and potash - 30 kg/ha). Gypsum was applied on the basis of laboratory estimated gypsum requirement for each farmer field separately before start of experiment (Table 227).

Table 224. Effect of different doses of gypsum on grain yield (t/ha) of wheat

Treatments	Name of the farmers					Mean
	Badrilal	Motiram	Babulal	Dinesh	Mangilal	
			2008-09			
Control	4.96	4.16	4.53	4.79	4.93	4.68
25% GR	5.41	4.50	4.83	4.71	5.20	4.93
50% GR	5.79	4.74	5.32	5.11	5.43	5.28
75% GR	6.02	5.07	5.11	5.06	5.81	5.41
CD (5%)						0.21
			2009-10			
Control	3.00	2.90	2.70	2.75	4.80	3.23
25% GR	5.00	4.25	4.60	4.75	5.15	4.75
50% GR	5.50	4.75	5.10	5.00	5.30	5.13
75% GR	5.65	4.90	5.30	5.30	5.50	5.33
CD (5%)						0.31

Table 225. Effect of different doses of gypsum application on ESP after harvest of wheat

Treatments	Name of the farmers					Mean
	Babulal	Mangilal	Dinesh	Motiram	Badrilal	
			2008-09			
Control	22.3	20.5	22.9	17.5	19.2	20.5
25% GR	20.2	19.0	18.6	17.0	18.8	18.7
50% GR	19.0	17.7	17.8	15.2	17.5	17.4
75% GR	18.0	17.2	17.3	15.2	17.4	17.0
CD (5%)						1.08
			2009-10			
Control	21.8	19.9	22.1	17.2	18.8	19.9
25% GR	19.9	19.1	18.5	17.2	18.5	18.6
50% GR	19.1	18.0	17.7	15.3	17.4	17.5
75% GR	18.3	17.2	17.2	14.7	17.2	16.9

Table 226. Details of the trials conducted on farmer's field (Barwaha, Khargone district)

Name of the farmer	Village	Area/plot (m)	Variety	Date of sowing
		2008-09		
Pappu Patel	Pipliya	20 x 25	JK-666	01.07.2008
Balya	Pipliya	20 x 25	Ankur-9	03.07.2008
Bhagwan/Hira singh	Barlai	20 x 25	Ankur-9	25.06.2008
Bhagwan/ Laxman	Barlai	20 x 25	Mallika	22.06.2008
SAS Research Farm	Bapalgaon	20 x 25	RCH-2	28.06.2008
		2009-10		
Pappu Patel	Pipliya	20 x 25	JK-666	05.07.2009
Balya	Pipliya	20 x 25	Ankur-9	30.06.2009
Bhagwan/Hira singh	Barlai	20 x 25	Ankur-9	25.06.2009
Bhagwan/ Laxman	Barlai	20 x 25	Mallika	26.06.2009
SAS Research Farm	Bapalgaon	20 x 25	RCH-2	30.06.2009

Table 227. Initial soil properties of Farmers' field

Name of the farmer	pH_2	EC_2 (dS/m)	CEC (cmol(+)/kg)	ESP	GR (t/ha)
Pappu Patel	8.4	1.39	50.1	26.4	12.4
Balya	8.5	1.29	45.2	28.8	13.8
Bhagwan/Hira singh	8.4	1.43	40.0	26.7	10.3
Bhagwan/ Laxman	8.3	1.56	45.9	24.0	11.0
SAS Farm	8.5	1.47	38.6	30.7	14.0

The data in Table 228 revealed that application of gypsum (@ 50 and 75% GR) significantly increased seed cotton yield over control as well as 25% GR. However, the differences between 50% GR and 75% GR were statistically non-significant. The perusal of the data depicted in Table 229 revealed that ESP decreased with gypsum application as compared to untreated soil. Lowest ESP was observed under 75% GR which were statistically at par with 50% GR.

Table 228. Effect of different doses of gypsum on Seed cotton yield (t/ha)

Treatments	Name of the farmers					Mean
	Pappu	Balya	Bhagwan/ Hira	Bhagwan/ Laxman	SAS Farm	
			2008-09			
Control	1.11	1.18	1.23	1.14	1.30	1.19
25% GR	1.14	1.21	1.22	1.18	1.33	1.21
50% GR	1.18	1.29	1.29	1.21	1.39	1.27
75% GR	1.20	1.27	1.26	1.22	1.38	1.26
CD (5%)						0.02
			2009-10			
Control	0.75	0.85	0.80	0.90	0.80	0.82
25% GR	1.10	1.15	1.20	1.15	1.25	1.17
50% GR	1.20	1.20	1.20	1.25	1.25	1.22
75% GR	1.20	1.25	1.25	1.25	1.30	1.25
CD (5%)						0.08

Table 229. Effect of different doses of gypsum application on ESP

Treatments	Name of the farmers					Mean
	Pappu	Balya	Bhagwan/ Hira	Bhagwan/ Laxman	SAS Farm	
			2008-09			
Control	26.6	29.3	27.3	24.5	31.0	27.8
25% GR	22.1	24.5	23.2	20.0	25.8	23.1
50% GR	19.9	21.0	20.0	18.9	22.0	20.4
75% GR	19.1	19.9	19.7	18.1	20.4	19.4
			2009-10			
Control	25.9	28.9	26.7	24.0	30.0	27.1
25% GR	21.8	24.0	22.9	19.9	24.5	22.6
50% GR	19.3	20.7	19.6	18.3	21.8	19.9
75% GR	18.8	19.1	19.1	18.0	20.2	19.0

Field Trials Conducted at Farmer's Field - Hisar

Technology for reclamation of sodic soil and water using gypsum application was demonstrated at the field of Sh. Tejpal Singh S/o Sh. Sahajad Singh (in 2008-09) and Sh. Virender Singh (in 2009-10), village Bhurjat, Distt. Mahendragarh. Five strips of variable gypsum application (0, 25, 50, 75 and 100 per cent neutralization of RSC) were made and wheat crop was grown. The requisite amount of gypsum in various treatments on the soil and water basis was applied in a single dose before sowing of crop and mixed well in the soil. Recommended cultural practices and fertilizer doses were applied for raising the crop. Uniform fertilizer applications were made in all the treatments. Irrigation schedule was based on the recommendations for the non-saline irrigated soils. During the year 2008-09, the crops were irrigated with sodic water having average RSC 10 me/l through sprinkler method, whereas, in year 2009-10, it was irrigated with sodic water of average RSC 13.8 me/l through sprinkler method. The initial soil and water parameters and other details of the demonstration are given in Table 230.

Table 230. Initial parameters of the demonstration at different fields (2008-09 and 2009-10)

Parameters	Sh. Tejpal Singh' field (2008-09)	Sh. Virender Singh's field (2009-10)
EC_{iw} (dS/m)	1.45	2.31
RSC (meq/l)	10.0	13.8
Soil pH (0-15 cm)	9.6	10.04
(15-30 cm)	9.6	10.00
(30-45 cm)	9.4	10.02
(45-60 cm)	8.9	9.94
Crop	Wheat	Wheat
Variety	PBW-502	PBW-502
Date of sowing	07.11.2008	15.11.2009
Date of harvesting	04.04.2009	02.04.2010
No. of irrigations	6	5

The yield of wheat crop increased significantly with the addition of increasing levels of gypsum application (Table 231). In both the years wheat crop yield in G_{100} treatment increased drastically by more than 2 times of the yield obtained in G_0 treatment. Appreciable increase in yields was also obtained in other treatments. During 2008-09, as a result of previous year's demonstration, 191 farmers of this village adopted the technology for the reclamation of sodic soils and waters by applying gypsum in their fields. About 200 tons of the gypsum was used by them. Consequently, the average yield of mustard and wheat increased by 0.8 to 1.0 tons per ha. During year 2009-10, the mean yield increased by 73.9, 120.5, 141.0 and 187.0 per cent, respectively, in G_{25}, G_{50}, G_{75} and G_{100} treatments as compared to control (Table 231). The variation in yield with respect to gypsum can be expressed by quadratic equation with a coefficient of correlation (R^2) of 0.984 (Fig. 58). However, increase in yield from G_{50} to G_{75} is insignificant.

Table 231. Yields (t/ha) of crops in relation to gypsum application at different farmer's field

Treatments	Yield (t/ha)	
	Sh. Tejpal Singh (2008-09)	Sh. Virender Singh (2009-10)
G_0	2.05	1.61
G_{25}	3.19	2.80
G_{50}	3.54	3.55
G_{75}	3.84	3.88
G_{100}	4.17	4.62
CD (5%)	0.27	0.49

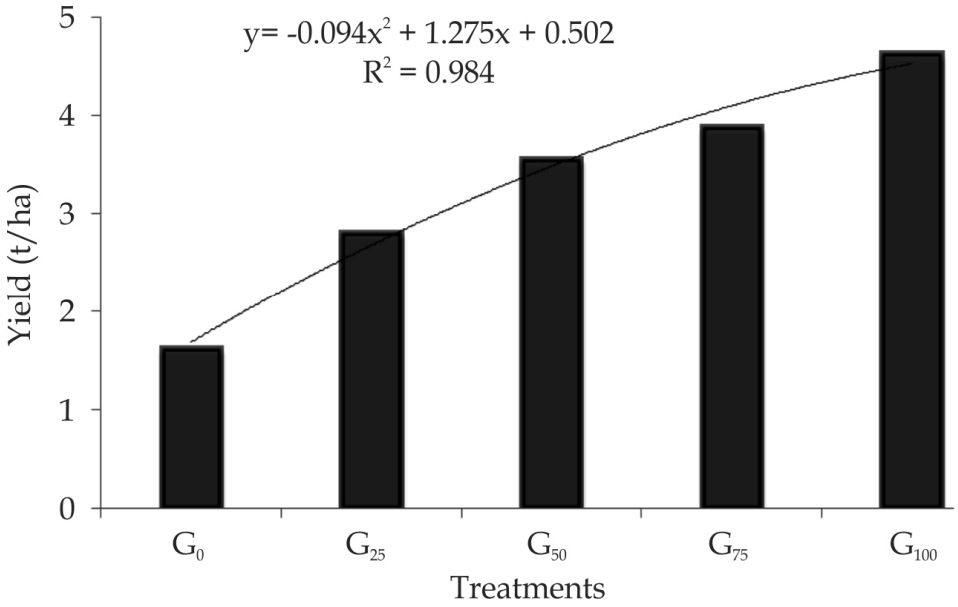


Fig. 58. Effect of gypsum application on the yield of wheat during 2009-10

F. AD-HOC STUDIES/NOTES

- Performance of Microbial Culture on Wheat Irrigated with Poor Quality Waters -Hisar
- Performance of different Paddy and Wheat Varieties under Sodic Vertisols –Indore

Performance of Microbial Culture on Wheat Crop Irrigated with Poor Quality Waters - Hisar

A study was conducted at CCS HAU, Hisar during 2009-10 to evaluate the performance of microbial culture on the wheat crop when irrigated with saline water of EC 8 dS/m. Treatments consisted of two irrigation waters, Canal water (EC=0.22 dS/m) and saline water (EC 8 dS/m) and four microbial cultures, Control, MAC-27 (parent strain), ST-3 (Salt tolerant) and ST-24 (Salt tolerant) replicated six times with plot size of 5.4 m x 3.0 m. One parent strain and two salt tolerant microbial cultures were quoted to seed of the wheat at the time of sowing. Recommended cultural practices and fertilizer doses were applied for raising the crops. The crops were harvested at maturity and yield data were recorded for each plot. The soil samples were collected before sowing and after harvest of crops.

The grain yield of wheat decreased in saline irrigation as compared to control (Table 232). The mean reduction in saline water irrigation was 9.08 per cent as compared to canal water. The maximum mean yield was obtained with ST-3 inoculation. Under saline water irrigation, the relative yield increase was 7.58, 6.39 and 5.77 per cent by inoculation of strains such as ST-3, ST-24 and MAC-27, respectively. The EC_e build-up in saline water was 10.4 dS/m, whereas, in canal water, it was 3.4 dS/m at the harvesting of the crop.

Table 232. Effect of salinity on grain yield (t/ha) of wheat in relation to inoculation of microbial cultures

Microbial cultures	Canal water	Saline water (EC 8.0 dS/m)	Mean
Control	4.21	3.80	4.01
ST-3	4.59	4.09	4.34
ST-24	4.32	4.02	4.17
MAC-27	4.43	4.04	4.24
Mean	4.39	3.99	
CD (5%)	Salinity (S) : 0.219	Microbial culture : NS	S x M : NS

Canal water irrigated plants had more per cent nitrogen when inoculated with MAC-27 as compared to ST-3 (Table 233). However, reverse trend was observed under saline water irrigation. Salt tolerant strain resulted in maximum per cent nitrogen accumulation under saline irrigated conditions.

Table 233. Effect of different inoculants on the nitrogen status in the straw and soil

Treatments	Straw nitrogen (%)		Soil nitrogen (mg/g)	
	Canal water	Saline water	Canal water	Saline water
Control	0.436	0.412	0.039	0.024
ST-3	0.464	0.461	0.049	0.042
ST-24	0.458	0.424	0.046	0.045
MAC-27	0.489	0.443	0.048	0.043

Total phosphorus accumulated by the plant was maximum when inoculated with MAC-27 under canal irrigated conditions (Table 234). Whereas, in saline irrigation, it was maximum when inoculated with ST-24 (salt tolerant). The viable count of Azotobacter was more in canal irrigated field as compared to saline irrigated fields except ST-3 (Table 235). Nitrogen contributed to soil by ST-3 was also maximum under saline conditions, thus, supporting the contention that it tolerate salinity and fix nitrogen under saline conditions.

Table 234. Effect of different inoculants on the phosphorous status in the straw and soil

Treatments	Straw phosphorus (mg/g)		Soil phosphorus (mg/g)	
	Canal water	Saline water	Canal water	Saline water
Control	0.535	0.213	0.072	0.046
ST-3	0.583	0.340	0.088	0.072
ST-24	0.588	0.666	0.098	0.086
MAC-27	0.658	0.398	0.094	0.098

Table 235. Viable count of different inoculants in canal and saline water irrigated fields

Treatments	Viable count (x 10^5 cfu/ml)	
	Canal water	Saline water
Control	26	29
ST-3	36	44
ST-24	121	34
MAC-27	152	102

Performance of different Paddy and Wheat Varieties under Sodic Vertisols - Indore

Paddy

The varieties tested showed outstanding performance at soil ESP 35±2. The yield performance of different varieties was in order of CSR 13 > CSR 23 & 27 > Kranti > CSR 10 > CSR 30 > CSR 36 on the basis of seed yield (Table 236).

Table 236. Growth, yield attributes and yield of paddy varieties

Varieties	Plant height (cm)	No. of tillers/ plant	Length of penicle (cm)	Yield (t/ha)	
				Grain	Straw
CSR 10	52.0	10.0	13.3	2.22	7.8
CSR 13	72.7	9.7	15.7	3.44	13.2
CSR 23	100.0	9.3	19.3	2.78	11.1
CSR 27	85.0	11.3	20.3	2.78	8.9
CSR 30	99.2	12.7	15.7	1.89	10.3
CSR 36	96.7	10.0	19.7	1.67	9.4
Kranti	62.5	9.0	19.0	2.67	4.6

Wheat

The varieties tested showed outstanding performance at soil ESP 35±2. The yield performance of different varieties was in order of HI-1077 >KRL – 19 >KRL – 213 >KRL – 1-4 >KRL – 210 on the basis of seed yield (Table 237).

Table 237. Growth characters and yield of wheat varieties

Varieties	Plant height (cm)	No. of tillers per plant	Length of ear head (cm)	Yield (t/ha)	
				Grain	Straw
KRL - 210	70.0	5.0	8.0	1.50	2.39
KRL - 213	65.0	5.0	8.0	1.94	2.50
KRL - 19	70.0	5.0	8.0	2.11	2.56
KRL 1-4	70.0	5.0	8.0	1.72	2.17
HI - 1077	75.0	5.0	10.0	2.17	3.39

G. GENERAL

G 1 : ORGANIZATION

G 2 : MANDATE OF COOPERATING CENTERS

G 3 : STAFF POSITION

G 4 : WEATHER DATA

G 5 : LIST OF PUBLICATIONS

G 6 : FINANCE

G 1: ORGANIZATION

The All India Coordinated Project on Use of Saline Water in Agriculture was first sanctioned during the IVth Five Year Plan under the aegis of Indian Council of Agricultural Research, New Delhi at four research centers namely Agra, Bapatla, Dharwad and Nagpur to undertake researches on saline water use for semi–arid areas with light textured soils, arid areas of black soils region, coastal areas and on the utilization of sewage water respectively. During the Fifth Five Year plan, the work of the project continued at the above four centers. In the Sixth Five Year Plan, four centers namely Kanpur, Indore, Jobner and Pali earlier associated with AICRP on Water Management and Soil Salinity were transferred to this Project whereas the Nagpur Center was dissociated. As the mandate of the Kanpur and Indore centers included reclamation and management of heavy textured alkali soils of alluvial and black soil regions, the Project was redesignated as All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture. Two of its centers located at Dharwad and Jobner were shifted to Gangawati (w.e.f. 01.04.1989) and Bikaner (w.e.f. 01.04.1990) respectively to work right at the locations having large chunks of land afflicted with salinity problems. During the Seventh Plan, Project continued at the above locations. During Eighth Five Year Plan, two new centers at Hisar and Tiruchirrapalli were added. These Centers started functioning from Ist January 1995 and 1997 respectively. During the Tenth Plan, Project continued with an outlay of Rs. 1090.00 lakh at these centers with the Coordinating Unit at Central Soil Salinity Research Institute, Karnal. The total outlay of the XI plan has been fixed at Rs. 2125.15 lakhs including the state share of Rs. 436.52 lakhs. The center wise mandate of the project is as follows:

G 2: MANDATES FOR COOPERATING CENTERS

Centre	**Mandate**
Agra	1. Water quality limits in relation to cropping system 2. Develop strategies for conjunctive use of saline and canal water 3. Improving the nutrient use efficiency in saline environment 4. Improved irrigation techniques and salt water management 5. Rain water management for salinity control 6. Alternate land use through agro-forestry and horticulture 7. Operational research for saline water use
Bapatla	1. Water quality and soil surveys and monitoring of benchmark sites 2. Crop-water production functions with saline water in coastal sands 3. Water quality limits with improved irrigation technologies 4. Improved Dorouv technology 5. Upconing problems of sea water in coastal sandy soils 6. Fertility management of saline coastal sandy soils. 7. Operational research on dorouv technology/saline water use 8. Reclamation of abandoned aqua ponds
Bikaner	1. Water quality surveys 2. Salt and water balance in gypsiferous soils of the IGNP Command 3. Irrigation management for saline water use 4. Drainage for control of salinity and water logging 5. Develop practices for use of nitrate and fluoride rich waters 6. Nutrient management of saline gypsiferous soils
Gangawati	1. Ground water quality surveys 2. Performance evaluation of drainage system in T.B.P. command 3. Reuse of drainage effluents/conjunctive use 4. Drainage requirement of crops in saline black soils 5. Performance of tree species in saline black soils including bio-drainage 6. Organic materials for improving productivity of saline soils 7. Tolerance of medicinal and aromatic plants to soil salinity 8. Reclamation of rain fed alkali lands

Hisar	1. Ground water quality surveys 2. Conjunctive use of canal and saline ground/drainage waters 3. Water production functions under salt stress conditions 4. Water quality guidelines for sprinklers/drip systems 5. Modelling crop yields under salt stress and strategies for mitigation 6. Management of alkali water for vegetable production
Indore	1. Ground water and soil surveys 2. Management of heavy textured alkali soils 3. Crop-water production functions for alkali black soils 4. Develop parameters for incorporating the effect of Cl/SO_4, Mg/Ca and SAR on sodification and soil permeability 5. Hydrosalinity modelling in Omkeshwar Command 6. Alternate land use of alkali black soils for agro-forestry 7. Tilerance of medicinal and aromatic plants to soil alkali stress 8. Management of wastewaters
Kanpur	1. Water treatment techniques for use of alkali water 2. Conjunctive use of alkali and canal water 3. Performance of tree species in alkali soils 4. Fertility management under conditions of alkali water use 5. Soil/ land/ water resource inventories in Ramganga/Sharda Sahayak Command 6. Resource conservation technologies for alkali soils 7. Salt tolerance studies on crop cultivars
Tiruchirapalli	1. Ground water quality surveys of Tamil Nadu 2. Mitigation strategies for adverse effects of salts on soil and crops 3. Conjunctive use of poor quality ground and canal waters 4. Survey of poor quality ground waters and salt affected soils 5. Alternate land use of salt-affected soils through agro-forestry 6. Multi-enterprise agriculture for higher income 7. Use of Distillery Spent wash for alkali land and water reclamation
Net work trials	1. Identification of appropriate cultivars of crops for saline/alkali environments in different agro-ecological regions 2. Water quality/salt affected soil resource inventories/mapping
Coordinating Unit	1. Developing guidelines on use of saline water 2. Use of saline water in agro-forestry 3. Modelling salt and water transport and crop response in saline environment 4. Generating chemical/physical parameters for computers models 5. Management of domestic and industrial wastewaters 6. Bio-drainage and wastewater disposal strategies 7. Management of ad-hoc projects approved by the council

G 3: STAFF POSITION

STAFF POSITION AT THE COOPERATING CENTERS

X plan	Agra	Bapatla	Bikaner	Gang–awati	Hisar	Indore	Kanpur	Tiruch–irapalli	Total
Scientific	4	6	5	5	4	5	4	4	37
Technical	6	6	5	5	4	6	6	4	42
Administrative	1	1	1	1	1	1	1	1	8
Supporting	2	2	2	2	2	2	2	2	16
Total	13	15	13	13	11	14	13	11	103

POST WISE STAFF POSITION AS ON 31. 03. 2011

Name of the post	Coordinating Unit, Karnal	Centers							
		Indore	Kanpur	Bikaner	Agra	Bapatla	Ganga–wati	Tiruch–irapalli	Hisar
Project Coordinator	1	–	–	–	–	–	–	–	–
Soil Scientist	1	–	–	1	–	1	–	–	–
Soil Chemist	-	1	1(1)	1	1(1)	–	–	1	1
Agronomist	1	–	–	–	–	–	–	–	–
Drainage Engineer	–	1	–	–	–	–	–	–	–
Soil Physicist	1(1)	–	1	–	–	–	–	–	–
Jr. Soil Chemist	1(1)	1	–	1	1	1(1)	1	1	1
Jr. Soil Physicist	–	1	–	–	1	–	–	–	–
Jr. Drainage Eng.	–	–	–	1	–	1	1	–	–
Soil Water Eng.	–	–	–	–	–	1	1	1	1
Jr. Plant Physio.	–	–	1	–	–	–	–	–	–
Jr. Agronomist	-	–	–	1(1)	1	1	1	1	1
Jr. Soil Survey Officer	–	1	1	–	–	–	–	–	–
Tech. Officer	2	–	–	–	–	–	–	–	–
STA	–	2	3(3)	–	2	–	–	–	–
Overseer	–	–	1	–	–	–	–	–	–
Lab. Tech.	1	–	–	–	–	–	–	–	–
Tracer	--	–	–	–	–	–	–	–	–
Field Asstt.	–	1	–	1	2(1)	1	1	1	1
Fieldman	–	1	–	–	–	–	–	–	–
Lab. Asstt.	-	1	1(1)	1	1	2	1	1	1
UDC	1	1	1	1(1)	1	1	1	1	1
Jr. Steno.	-	–	–	–	–	–	–	–	–
Jeep Driver	–	1	1	1	1	1	1(1)	1	1
Lab. Attendant	3(2)	1	1	1	1	1	1	1	1
Messenger	-	1	1	1	1	1	1	1	1

( ) Vacant position

STAFF POSITION AS ON 31. 03. 2011

Name of the post	No.	Name of incumbent	Date of joining	Date of leaving
		COORDINATING UNIT, CSSRI, KARNAL		
Project Coordinator	1	Dr. S. K. Gupta	07.06.2007	Contd.
Pr. Scientist (Pedology)	1	Dr. Anil R. Chinchmalatpure	23.09.2010	Contd.
Sr. Agronomist	1	Dr. R. L. Meena	18.07.2007	Contd.
Sr. Tech. Officer	1	Sh. S.P. Gupta	03.07.2007	Contd.
Technical officer	1	Sh. Brij Mohan	04.10.1988	Contd.
Personal Assistant	1	Mrs. Rita Ahuja	25.04.1992	Contd.
Messenger	1	Sukhbir Singh		Contd.
		COOPERATING CENTRES		
AGRA				
Soil Chemist	1	Vacant –Taken over charge by Dr Bhu Dayal	30.06.2009	Contd.
Jr. Soil Chemist	1	Dr. Bhu Dayal	30.11.1987	Contd.
Jr. Soil Physicist	1	Dr. R.B. Singh	30.11.1987	Contd.
Jr. Agronomist	1	Dr. S.K. Chauhan	15.03.1996	Contd.
Sr. Tech. Assistant	2	Sh. R.S. Chauhan	01.08.1991	Contd.
(Soils)		Dr. P.K. Shishodia	11.07.1994	Contd.
UDC	1	Sh. Rajeev Chauhan	04.09.1991	Contd.
Field Assistant	2	Vacant	-	-
		Sh. Vijendra Singh	23.07.1973	Contd.
Lab Assistant	1	Sh. Sarnam Singh	18.12.1989	Contd.
Driver	1	Sh. Ram Sevak		
Lab. Attendant	1	Sh. Devi Singh	28.08.1972	Contd.
Messenger	1	Sh. Kishan Singh	23.07.1980	Contd.
BAPATLA				
Principal Scientist	1	Dr. V.Shankra Rao	24.02.2005	25.08.2008
		Dr. P.R.K. Prasad	08.11.2008	20.09.2010
		Dr. G.V. Lakshmi	01.10.2010	Contd.
Soil Scientist/	1	Dr. G.V. Lakshmi	10.01.2006	30.09.2010
Senior Scientist		Dr. V.Shankra Rao	26.08.2008	02.11.2008
		Dr. P.R.K. Prasad	08.11.2008	30.09.2010
		Vacant		
Jr. Chemist (SS)	1	Dr. P. Ravinder Babu	04.02.2004	08.10.2010
		Vacant		
Scientist (Agronomist)	1	Sh. Y. Radha Krishna	27.04.1999	14.07.2008
		Sh. P. Venkata Rao	19.02.2010	Contd.
Scientist (SWE) –I	1	Sh. M. Raghubabu	16.10.1993	Contd.
Scientist (SWE) –II	1	Vacant	-	-
Sr. Assistant	1	Sh. M. Raju	28.10.2005	Contd.
Lab Assistant	3	Sh. S. Baba Vali	04.09.1990	Contd.
		Sh. S.K. Mastan Vali	07.07.2005	16.06.2010
		Sh. S.K. Moulali	03.05.2006	Contd.
Field Assistant	2	Sh. Syed Khasim	19.05.2005	Contd.
		Sh. K. Siva Kumar	12.07.2006	Contd.
Lab Attendent	1	Sh. D.V. Siva Rao	16.07.1992	Contd.

Driver	1	Sh. D.V. Brahmam	13.09.2007	Contd.
Messenger	1	Sh. A. Mark	29.12.1995	Contd.
BIKANER				
Chief Scientist & O/I	1	Vacant	-	-
		Dr. B.L.Verma	31.12.2005	2009
Soil Chemist	1	Vacant	-	-
Jr. Soil Chemist	1	Dr. Yogesh Sharma*	07.05.1996	Contd.
Jr. Agronomist	1	Vacant	–	–
Jr. Drainage Engineer	1	Er. A.K. Singh	10.09.2001	Contd.
Technical Assistant	2	Vacant	-	-
		Sh. B. L. Naik**	05.11.2007	Contd.
Field Assistant	1	Sh. B.C. Kumawat	18.07.2001	Contd.
UDC	1	Sh. Ram Lal Meena	01.02.2008	Contd.
Lab. Assistant	1	Sh. S.K.Bazad	14.02.1994	Contd.
Driver	1	Sh. Man Singh	03.08.1994	Contd.
Lab. Attendant	1	Sh. Keshu Ram	17.07.1995	Contd.
Messenger	1	Sh. Ganesh Ram	25.03.1994	Contd.
*Working as OIC against the post,		** AAO working as TA		
GANGAWATI				
Chief Scientist	1	Dr. S.L. Budihal	02.22.2009	Contd.
Scientist (Soil Science)	1	Dr M. Hebbara	21.08.1988	18.10.2009
		Dr. Vishwanath J.	18.10.2009	Contd.
Scientist (SWE)	1	Er. Subhas Balagnavi	15. 07. 1999	Contd.
Jr. Drainage Engineer	1	Sh. A.V. Karegoudar	12.12.2009	Contd.
Jr. Agronomist	1	Sh. G. Ravishankar	04.10.1995	17.10.2008
		Dr. B.G. Mastan Reddy	17.10.2008	02.12.2009
		Ms. Roopashree D.H.	02.12.2009	Contd.
Junior Asstt.	1	Smt. Renuka Benakanadoni	21.12.2009	Contd.
Field Assistant	2	Sh. K.Veeranna	02.04.1998	Contd.
		Sh. P.Balasaab	19.11.2001	Contd.
Lab Assistant	2	Sh. B. Nagaraj	26.09.2003	Contd.
		Vacant	–	–
L.V. Driver	1	Sh. Huligeppa Naik	27.07.2006	Contd.
Lab. Attendant	1	Vacant	-	-
Messenger	1	Sh. M. Srinath	27.07.1998	Contd.
HISAR				
Soil Scientist & OIC	1	Dr. S.K. Sharma	08.08.2002	Contd.
Soil Chemist	1	Dr. Vinod K. Phogat	19.06.1997	Contd.
Soil Water Engineer	1	Dr. Sanjay Kumar	10.06.1997	Contd.
Agronomist	1	Dr. Satyavan	11.03.1997	Contd.
Sr. Technical Assistant	2	Sh. D.S. Dahiya	27.07.2002	31.03.2010
		Vacant	–	–
Field Assistant	1	Sh. Jagdish Chander	03.02.2001	Contd.
Lab. Assistant	1	Sh. Ram Jivan	11.07.2007	30.06.2008
		Sh. Dhan Singh	02.03.2009	Contd.
LDC	1	Smt. Poonam Pahuja	22.09.1999	Contd.
Lab Attendant	1	Sh. Surat Singh	25.05.2010	Contd.
Messenger	1	Sh. Karan Singh	01.08.2001	26.07.2010
		Sh. Desh Raj	27.07.2010	Contd.

INDORE

Soil Chemist &OIC	1	Dr. S.K. Verma	19.09.2003	02.09.2008
		Dr. U.R. Khandkar	02.09.2008	Contd.
Drainage Engineer	1	Er. R.K. Sharma	09.05.2000	Contd.
Jr. Soil Survey Officer	1	Dr. U.R. Khandkar	01.07.2002	02.09.2008
		Sh. B.B. Parmar	02.09.2009	Contd.
Jr. Soil Chemist	1	Dr. K.S. Bangar	22.02.1996	Contd.
Jr. Soil Physicist	1	Dr. S.P.K. Unni	15.09.2003	Contd.
Technical Assistant	2	Sh. S.C. Tiwari	04.03.1989	Contd.
		Sh. N.S. Tomar *	04.04.1996	Contd.
UDC	1	Mr. Dinesh Sharma	30.05.2006	Contd.
Field Assistant	1	Sh. T.L. Dhamne	01.07.2000	Contd.
Field man cum– T. D.[1]	1	Sh. S.R. Hirve	25.08.2003	Contd.
Lab. Assistant	1	Ms. R. Ansari	16.11.1995	Contd.
Jeep Driver	1	Sh. Kailash Mandloi	19.04.2007	29.10.2008
		Sh. Dinesh Mandloi	02.02.2009	Contd.
Lab. Attendant	1	Sh.Uttam Ingle	01.04.1984	30.11.2009
Messenger	1	Mrs. Rama Gupta	28.08.2003	Contd.

* Agricultural Extension Officer posted against the post of Technical Assistant; [1] Tractor Driver

KANPUR

Soil Chemist	1	Dr. Samir Pal	01.12.2006	-
Soil Physicist	1	Dr. Ravendra Kumar OIC	09.05.2008	-
Asstt. Agronomist	1	Dr. Rajendra Singh	01.10.2004	-
Asstt. Soil Survey Officer	1	Dr. K.N. Singh	01.07.2003	-
Sr.Technical Assistant	1	Sh. G.S. Tripathi	01.09.2004	-
Field Assistant	2	Sh. Ved Prakash Yadav	31.01.2006	-
		Sh. N.B. Singh	-	-
UDC	1	Sh.Paramhans Verma	15.11.2010	-
Lab. Assistant	1	Sh. P.S.Katiyar	01.09.2004	-
Driver	1	Sh. Vijay Kumar	15.10.2009	-
Lab. Attendant	1	Sh. Gaya Prasad	01.05.1988	-
Messenger	1	Sh. Ram Murti	01.10.2010	-

TIRUCHIRAPALLI

Soil Chemist & O/I	1	Dr. M.Sheik Dawood	04.03.2010	Contd.
Jr. Agronomist	1	Dr. S. Panneerselvam	10.05.2006	29.05.2008
		Dr. R. Kavimani	30.05.2008	04.01.2010
Jr. Soil Water Engineer	1	Dr. N. Anandraj	14.05.2007	26.05.2008
		Dr. K. Sara Parwin Banu	27.05.2008	30.07.2010
Jr. Soil Chemist	1	Dr. L. Chitra	08.05.2008	Contd.
		Dr. M. Bhaskar	09.05.2008	Contd.
Sr. Technical Assistant	2	Sh. K. Karikalan	14.12.2000	Contd.
		Sh. S. Senthil Kumar	17.11.2008	Contd.
Field Assistant	1	Sh. A. Palanivelu	11.11.2003	Contd.
Lab. Assistant	1	Sh. P.Sakthivel	01.07.2003	Contd.
Lab. Attendant	1	Sh. S. Ponnan	21.08.1996	Contd.
UDC	1	Sh. C. Meenatchi	22.10.2008	Contd.
Messenger	1	Sh. V. Palaniyandi	01.04.1995	Contd.

G 4: WEATHER DATA (2008-2010)

AGRA

Latitude - 27^{0}20′ N **Longitude - 77^{0}90′ E**

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)	Water table (m)
	Maximum	Minimum				
			2008-2009			
April, 2008	38.2	21.6	59.0	010.6	8.0	12.2
May	39.9	24.4	40.0	045.1	7.1	12.0
June	35.8	24.7	71.0	147.5	5.2	11.6
July	35.9	24.8	70.7	110.1	4.5	13.6
August	32.9	26.0	91.8	120.3	3.8	13.5
September	33.7	25.5	92.4	226.8	3.4	13.6
October	34.8	20.4	89.0	151.3	3.5	13.6
November	29.7	14.5	85.5	000.0	3.1	13.8
December	25.1	09.9	89.5	000.0	1.4	13.7
January,2009	22.4	08.8	91.6	000.0	1.1	13.8
February	26.9	10.9	89.6	000.0	2.3	13.9
March	33.3	16.2	75.1	000.0	4.2	13.9
			2009-2010			
April, 2009	38.3	21.4	54.1	007.2	8.5	13.9
May	40.9	25.6	54.6	025.6	8.0	13.9
June	39.9	27.8	62.7	000.0	10.7	13.9
July	34.1	27.5	84.3	116.3	4.8	14.0
August	34.0	33.8	82.3	191.1	4.6	14.0
September	32.3	24.2	86.7	070.5	3.9	14.1
October	31.9	18.7	80.6	139.9	3.1	14.2
November	26.5	12.5	85.2	026.1	1.6	14.4
December	23.3	07.3	89.5	006.8	1.1	14.5
January,2010	19.4	05.9	89.4	008.3	1.0	14.5
February	27.2	10.5	89.4	013.8	1.4	14.7
March	33.2	13.9	75.2	000.0	4.7	13.9

BAPATLA

Latitude - 15° 54′ N **Longitude - 80° 29′ E**

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Decennial mean rainfall (mm)
	Maximum	Minimum			
		2008-2009			
April, 2008	24.81	33.6	75.98	13.3	25.1
May	27.6	41.9	49.50	1.7	40.2
June	26.9	37.6	64.00	121.7	129.7
July	25.8	35.2	72.00	177.2	128.6
August	25.0	32.7	80.50	193.5	170.0
September	25.33	33.72	73.33	90.4	169.5
October	23.9	32.7	76.5	79.1	225.8
November	26.1	30.8	80.5	214.0	54.9
December	19.2	30.4	81.0	2.2	19.5
January,2009	17.28	30.06	77.18	0.0	7.9
February	19.6	31.6	80.5	0.0	18.1
March	22.17	33.2	77.53	0.0	13.1
		2009-2010			
April, 2009	35.15	26.00	73.50	-	
May	37.20	27.30	70.50	38.2	
June	28.30	37.20	50.50	27.4	127.0
July	27.50	37.30	56.50	30.4	123.6
August	26.20	36.10	69.50	231.0	172.2
September	25.50	34.40	74.50	216.1	175.3
October	24.40	33.40	73.50	3.6	203.4
November	22.70	30.70	85.50	147.9	69.7
December	19.10	30.00	79.00	5.0	20.0
January,2010	19.00	30.10	81.00	14.1	9.3
February	19.30	30.80	79.50	-	13.1
March	23.60	33.40	79.50	-	13.1

BIKANER

Latitude – 28° 01′ N **Longitude – 73° 35′ E**

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Wind velocity (km/hr)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum			
			2008-2009				
April, 2008	36.6	19.3	52	21	043.2	7.7	08.3
May	40.3	25.7	55	30	028.4	12.7	12.7
June	39.6	28.0	63	34	031.1	12.4	11.0
July	39.0	28.9	64	36	011.4	12.3	11.2
August	36.2	26.7	79	50	123.0	9.3	07.7
September	36.4	24.7	74	38	000.0	7.8	08.8
October	37.3	21.1	54	19	000.0	5.7	07.0
November	31.3	12.8	57	20	000.0	3.7	04.3
December	24.9	9.8	77	35	002.6	7.5	05.0
January, 2009	23.0	07.5	77	33	006.0	4.8	02.3
February	27.4	11.9	70	23	000.0	5.2	03.8
March	32.9	16.3	57	18	003.0	7.2	07.1
			2009-2010				
April, 2009	37.7	23.1	37	11	000.0	7.3	09.2
May	44.9	28.8	40	14	028.0	10.0	14.0
June	41.5	27.2	50	22	031.1	11.3	12.9
July	38.3	27.4	73	46	206.0	9.2	09.1
August	38.1	28.4	68	42	045.0	10.8	10.0
September	38.7	25.9	68	27	023.8	7.4	07.5
October	36.3	22.0	48	21	000.0	5.1	07.0
November	29.5	14.5	61	23	000.0	3.4	04.0
December	25.4	11.0	67	23	001.0	3.7	02.5
January, 2010	22.0	7.8	86	35	001.0	4.5	01.9
February	27.0	12.4	59	17	000.5	5.6	04.7
March	36.2	20.7	47	14	000.0	6.6	07.0

GANGAWATI

Latitude – 15° 00′N **Longitude – 76° 00′ E**

Months	Temperature (°C)		Relative humidity (%)		Total rainfall (mm)	Evaporation* (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2008-2009			
April, 2008	35.0	22.1	80.5	60.0	000.0	
May	37.9	23.4	87.5	41.4	027.4	
June	33.9	23.1	85.9	47.6	058.4	
July	33.1	22.8	85.3	57.8	012.7	
August	30.0	22.0	87.0	71.0	012.1	
September	30.0	21.0	89.0	73.0	118.9	
October	31.0	19.5	83.0	68.0	044.2	
November	29.6	16.3	80.0	71.0	043.0	
December	30.0	15.0	78.0	66.0	000.0	
January,2009	29.5	15.0	74.0	65.0	000.0	
February	33.3	17.0	67.0	62.0	000.0	
March	34.8	19.7	77.5	72.2	007.0	
			2009-2010			
April, 2009	37.7	22.6	70.3	63.5	000.0	
May	37.0	23.0	71.0	60.0	102.0	
June	33.0	22.0	72.0	70.0	086.5	
July	31.0	22.6	77.0	77.0	002.0	
August	32.0	21.0	77.0	74.0	204.7	
September	30.4	21.3	84.9	81.7	392.0	
October	30.0	25.0	80.0	74.0	357.3	
November	29.0	18.0	86.0	71.0	074.0	
December	28.0	15.0	81.0	68.0	036.0	
January,2010	28.0	16.0	87.0	70.0	000.0	
February	32.0	17.0	85.0	62.0	000.0	
March	35.6	19.3	79.5	61.0	007.0	

* Evaporation data not available

HISAR

Latitude - 29° 10′ N **Longitude - 75° 46′ E**

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2008-2009			
April, 2008	35.4	17.1	63.0	26.0	013.9	7.3
May	38.0	22.7	60.0	32.0	052.9	7.9
June	36.2	25.6	80.0	59.0	108.9	5.3
July	36.2	26.4	82.0	58.0	162.1	4.9
August	33.7	25.4	91.0	72.0	129.1	4.3
September	33.6	22.4	87.0	54.0	096.0	4.4
October	33.9	18.8	84.0	37.0	005.3	3.7
November	28.9	10.6	90.0	33.0	003.2	2.3
December	23.5	06.8	94.0	48.0	000.8	1.5
January, 2009	20.1	05.8	97.0	53.0	010.3	1.4
February	24.1	07.3	93.0	45.0	006.1	2.1
March	29.4	11.8	89.0	40.0	004.1	3.7
			2009-2010			
April, 2009	35.8	17.3	62.5	29.8	024.9	7.4
May	40.8	23.7	54.7	25.5	038.2	9.3
June	41.5	25.2	54.7	25.1	029.4	10.4
July	36.7	26.4	77.7	57.8	092.4	6.9
August	38.0	26.8	76.0	49.7	014.0	6.8
September	34.4	22.5	88.5	51.1	239.9	4.7
October	33.4	15.5	84.1	29.3	000.0	3.8
November	27.1	09.9	91.1	41.2	000.0	2.1
December	23.1	04.9	89.6	36.6	000.0	1.6
January, 2010	17.3	05.9	97.8	69.3	011.5	0.9
February	25.8	07.4	90.6	45.5	007.6	2.3
March	34.9	16.7	78.0	31.0	002.5	4.2

INDORE

Latitude – 22° 14′ N **Longitude - 76° 01′ E**

Months	Temperature* (°C)		Relative humidity* (%)		Rainfall (mm)	Evaporation (mm/month)
	Maximum	Minimum	Maximum	Minimum		
			2008-2009			
April, 2008	-	-	-	-	000.0	318.5
May	-	-	-	-	000.0	488.0
June	-	-	-	-	025.2	335.5
July	-	-	-	-	158.1	231.5
August	-	-	-	-	119.6	101.0
September	-	-	-	-	069.5	114.5
October	-	-	-	-	007.6	131.0
November	-	-	-	-	039.1	111.0
December	-	-	-	-	000.0	079.0
January, 2009	-	-	-	-	003.7	079.5
February	-	-	-	-	000.0	105.5
March	-	-	-	-	000.0	247.5
			2009-2010			
April, 2009	-	-	-	-	000.0	403.0
May	-	-	-	-	071.0	445.0
June	-	-	-	-	069.2	429.5
July	-	-	-	-	331.2	112.0
August	-	-	-	-	070.2	115.0
September	-	-	-	-	052.7	136.0
October	-	-	-	-	029.7	143.0
November	-	-	-	-	059.5	080.5
December	-	-	-	-	007.5	068.5
January, 2010	-	-	-	-	003.7	095.0
February	-	-	-	-	006.7	100.5
March	-	-	-	-	005.3	208.5

* Data not available

KANPUR

Latitude – 29° 27′ N **Longitude – 80° 20′ E**

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2008-2009			
April, 2008	37.8	20.0	49.2	22.5	009.5	4.9
May	39.2	24.8	55.1	31.1	004.8	8.1
June	34.0	25.8	82.2	64.8	389.8	4.3
July	31.0	25.5	90.9	76.5	465.8	1.7
August	32.3	25.6	90.6	76.3	320.4	2.5
September	34.1	24.2	85.1	62.7	063.4	5.6
October	26.5	18.9	83.1	45.2	000.0	4.0
November	28.5	12.8	87.9	42.1	000.0	1.7
December	24.8	24.4	92.4	53.0	000.0	1.0
January, 2009	22.3	09.0	91.6	52.6	004.0	1.5
February	26.5	10.3	84.5	39.9	001.5	2.8
March	32.5	14.3	71.1	31.0	006.3	0.8
			2009-2010			
April, 2009	39.2	20.6	53.6	30.5	006.3	7.6
May	38.8	35.0	65.3	32.6	039.5	10.2
June	41.7	26.8	58.0	29.6	021.0	11.7
July	35.4	26.8	83.9	65.1	184.3	8.1
August	33.0	26.5	85.0	72.0	000.0	5.8
September	34.4	24.5	84.9	62.2	004.8	6.5
October	31.5	17.7	85.1	44.6	117.2	5.3
November	27.3	12.9	86.7	43.3	003.0	3.4
December	23.7	09.0	90.7	43.7	009.8	3.8
January, 2010	24.0	08.8	90.0	48.0	000.0	1.4
February	30.4	14.6	75.0	35.0	000.0	4.2
March	38.6	20.2	68.0	20.0	000.0	6.4

KARNAL

Latitude – 29° 43′ N **Longitude – 76° 58′ E**

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2008-2009			
April, 2008	34.9	17.7	67.0	27.0	013.0	08.1
May	35.9	22.3	67.0	40.0	083.6	08.3
June	33.5	24.2	85.0	64.0	144.8	05.1
July	33.7	26.2	90.0	68.0	131.8	04.9
August	31.9	25.3	93.0	76.0	192.6	03.5
September	32.0	22.6	92.0	62.0	098.3	04.4
October	31.8	20.0	91.0	46.0	001.0	03.3
November	27.8	11.6	89.0	42.0	014.2	02.2
December	22.2	09.0	94.0	55.0	001.0	01.6
January, 2009	19.0	07.7	96.0	63.0	008.3	01.5
February	23.5	09.0	91.0	49.0	006.6	02.6
March	28.9	12.6	85.0	36.0	002.6	04.0
			2009-2010			
April, 2009	36.2	18.4	58.0	22.0	024.2	09.1
May	38.1	23.3	64.0	31.0	017.4	08.6
June	40.1	25.3	58.0	27.0	025.8	11.6
July	34.4	26.4	85.0	65.0	130.4	05.7
August	33.4	26.2	88.0	70.0	046.7	04.4
September	32.2	23.4	94.0	67.0	215.1	03.7
October	32.0	16.4	84.0	36.0	000.0	03.9
November	26.6	11.1	87.0	37.0	000.0	02.5
December	21.7	06.4	92.0	41.0	000.0	01.7
January, 2010	16.0	06.7	98.0	72.0	000.0	02.4
February	22.9	08.8	93.0	54.0	000.0	02.5
March	30.8	14.6	89.0	41.0	000.0	04.0

TIRUCHIRAPPALLI

Latitude – 10° 45′ N **Longitude – 78° 36′ E**

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2008-2009			
April, 2008	-*	-	-	-	-	-
May	-	-	-	-	-	-
June	36.8	27.6	88.5	59.8	000.0	7.4
July	36.1	26.4	89.3	64.2	144.0	8.1
August	35.4	25.9	92.0	69.9	075.2	7.9
September	35.2	25.3	88.9	79.6	023.8	6.8
October	34.6	24.6	89.0	80.5	013.1	7.2
November	31.0	22.1	89.9	87.7	406.2	4.7
December	30.6	25.3	93.4	87.0	053.0	0.8
January,2009	30.5	18.9	93.8	78.0	007.0	3.5
February	32.7	18.4	92.8	69.2	000.0	4.1
March	35.3	21.1	91.8	69.8	000.0	5.6
			2009-2010			
April, 2009	37.6	22.4	90.0	63.8	000.0	6.8
May	40.3	25.9	84.5	53.6	025.6	7.7
June	3.85	24.3	82.1	60.2	102.00	8.6
July	37.9	25.5	90.9	59.7	000.0	8.2
August	38.3	24.8	89.6	64.3	044.0	6.1
September	35.9	24.9	88.9	63.9	050.1	5.4
October	35.8	23.8	92.7	69.7	021.6	5.5
November	32.1	22.4	93.9	87.2	252.5	2.7
December	29.4	21.3	92.6	88.1	084.8	2.3
January,2010	30.4	20.2	90.1	74.5	006.2	3.2
February	25.5	21.8	86.2	72.4	000.0	3.1
March	36.5	22.3	92.4	70.7	000.0	6.1

* Data not available

G 5: LIST OF PUBLICATIONS (2008-2010)

AGRA

Research Papers

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Chauhan, S.K., Chauhan , C.P.S and Singh, S.K. 2009. Effect of sowing method and date of sowing on germination and yield of cotton irrigated with saline water. *Annals of Agricultural Research*. (Accepted)

Seminar/Symposia Papers

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G – 6: FINANCE

The Eleventh Five Year Plan (2007–2012) was sanctioned by the Council vide letter N. 9-2/2007/IA-II dated 20.10.2008 with an outlay of Rs. 2125.15 lakhs (ICAR Share Rs. 1695.63 lakhs). The budget head and center wise statement of expenditure for 2008–2009 and 2009–10 is given below:

AGRA

Budget head	2008-09		2009-10	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	5200000	3886709	2300000	4196529
T.A. & P.O.L.	120000	75361	130000	114134
Contingencies				
Recurring	300000	296510	430000	421152
Non-recurring	350000	0	1100000	604666
Works	0	0	700000	639606
Total	5970000	4258580	4660000	5976087

BAPTALA

Budget head	Expenditure (ICAR share Rs in lakhs)	
	2008-09	2009-10
Pay & Allowances	3839940	4397508
T.A. & P.O.L.	61372	87952
Contingencies		
Recurring	343400	398286
Non-recurring	297050	956766
Works	0	240060
Total	4541762	6080572
ORP		
TA	46679	23661
RC	246870	212892
Total	293549	236553
Grand Total	4835311	6317125

BIKANER

Budget head	2008-09		2009-10	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	2800000	3381579	1600000	4048312
T.A. & P.O.L.	100000	98613	730000	62746
Contingencies				
Recurring	350000	342392	410000	379883
Non-recurring	300000	167008	416000	225595
Works	0	0	700000	0
Total	3550000	3989592	3856000	4716536

GANGAWATI

Budget head	2008-09		2009-10	
	Released ICAR share	ICAR share of expenditure	Released ICAR share	ICAR share of expenditure
Pay & Allowances	1950000	1240977	1025000	1401804
T.A. & P.O.L.	80000	90794	50000	80801
Contingencies				
Recurring	255000	348410	380000	302822
Non-recurring	300000	15900	150000	118169
Total	2585000	1696081	1605000	1903596

HISAR

Budget head	2008-09		2009-10	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	3466600	2886099	4686300	4610082
T.A. & P.O.L.	133300	118159	60000	54230
Contingencies				
Recurring	533300	337796	1973330	1874419
Non-recurring	400000	69815	1026600	849151
Total	4533200	3411869	7746230	7387882
ICAR share	3399900	2558902	5809673	5540912

INDORE

Budget head	2008-09		2009-10	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	4540259	3970016	2933000	4153226
T.A. & P.O.L.	133333	83062	107000	106646
Contingencies				
Recurring	533333	498100	400000	398319
Non-Contingencies	400000	0	866000	21840
Total	5606925	4551178	4306000	4680031

KANPUR

Budget head	2008-09		2009-10	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	3627000	2977044	1625000	2413670
T.A. & P.O.L.	106000	99931	55000	42784
Contingencies				
Recurring	467000	427122	300000	243805
Non-recurring	467000	80352	850000	117579
Works	0	0	525000	525000
Total	4667000	3584449	3355000	3342838

KARNAL

Budget head	2008-09		2009-10	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	0	0	0	0
T.A. & P.O.L.	100000	100000	150000	149000
Contingencies				
Recurring	550000	550000	200000	200000
Non-recurring	0	0	0	0
Equipments	0	0	70000	70000
Total	650000	650000	420000	419000

TIRUCHIRAPALLI

Budget head	2008-09		2009-10	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	2133300	2402386	3960000	3141830
T.A. & P.O.L.	146600	144696	146600	145746
Contingencies				
Recurring	413300	413140	400000	399746
Non-recurring	0	0	726660	698810
Works	0	0	700000	699822
Total	2693200	2960222	5933260	5085954